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ABSTRACT

This program planning guide for a two-year postsecondary radiation protection technician program is designed for use with courses 17-22 of thirty-five included in the Nuclear Technology Series. The purpose of the guide is to describe the nuclear power field and its job categories for specialists, technicians, and operators; and to assist planners, administrators, faculty, and industrial and community educational advisors in establishing and conducting relevant training programs. The guide provides a model curriculum plan and suggests methods for adapting the modular materials to curricula tailored to specific localities or employer needs. Also included is information about educational facilities, equipment, staffing, and instructional materials needed for training technicians and operators in this field. Appended material includes the technical specialty courses and module titles and descriptions; suggested workforce needs survey instrument for radiation protection technicians; equipment list with cost, quantity, and vendor data; and suggested library references and materials. (A master index to the series and other suggested program guides are available--see CE 026 856 and CE 026 640-643.) (LRA)

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NUCLEAR TECHNOLOGY SERIES

RADIATION PROTECTION TECHNICIAN

A SUGGESTED PROGRAM PLANNING GUIDE

(REVISED JUNE 80)

CE026 639

U S DEPARTMENT OF HEALTH,
EDUCATION & WELFARE
NATIONAL INSTITUTE OF
EDUCATION

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1977

The Nuclear Technology Series consists of five curricula (see page 2):

Radiation Protection Technician.
Nuclear Reactor (Plant) Operator Trainee.
Nuclear Materials Processing Technician.
Nuclear Quality-Assurance/Quality-Control Technician.
Nuclear Instrumentation and Control Technician.

The Radiation Protection Technician curriculum consists of the following 12 technical specialty courses including 81 instructional modules (see Appendix B for module titles and descriptions):

Radiation Physics.
Radiation Protection I.
Introduction to Nuclear Systems.
Radiation Detection and Measurement.
Power Plant Chemistry.
Introduction to Quality Assurance/Quality Control.
Radiation Protection II.
Radiological Emergencies.
Radiation Shielding.
Radiation Monitoring Techniques (Radiochemical).
Radioactive Materials Disposal and Management.
Advanced Radionuclide Analysis.

Availability: Instructional modules are available individually or by courses from:

Center for Occupational Research and Development
4800 Lakewood Drive
Waco, Texas 76710
Telephone (817) 772-8972

FOREWORD

In response to the needs of the nuclear industry, a curriculum has been designed and 81 instructional modules have been developed. These modules may be used by two-year, postsecondary technical institutions to train men and women to work as Radiation Protection Technicians. The instructional materials also are useful to employers for training or updating their employees in company-sponsored educational programs.

The purpose of this Guide is to describe the radiation protection field and its job categories for specialists, technicians and to assist planners, administrators, faculty and industrial and community educational advisors in establishing and conducting relevant training programs.

The Guide provides a model curriculum plan and suggests methods for adapting the modular materials to curricula tailored to specific localities or employer needs. Also included is information about educational facilities, equipment, staffing and instructional material needed for training technicians and operators in this field. This information is based on task inventories conducted by the Center for Occupational Research and Development staff and on the collective thinking of the National Steering Committee for Nuclear Technician Training, made up of employers, technical specialists and educators.

Funds for this project were provided under contract from the U.S. Office of Education, Bureau of Adult and Occupational Education, Mr. William M. Berndt, Project Officer. Additional assistance in the form of valuable advice, encouragement and guidance was provided by Dr. Walter J. Brooking, Project Monitor.

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Dr. Maurice W. Roney, Texas State Technical Institute.
Mr. W. Scott Fellows, Director of Special Programs,
Southern States Energy Board.

Second, the invaluable assistance of a dedicated National Steering Committee for Nuclear Technician Training merits special acknowledgment: the members of this committee are listed in Appendix A.

Thirdly, the quality and relevance of this curricula and the instructional materials owe much to the technical resource personnel, writers, module reviewers, and editors too numerous to identify by name but who must be recognized in their entirety.

Staff members of the Center for Occupational Research and Development who have contributed significantly to this entire project and to the materials contained in this guide include:

Mr. Vernon Woolf, Associate Project Director.
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Ms. Kay Liston, Project Coordinator.

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Project Director

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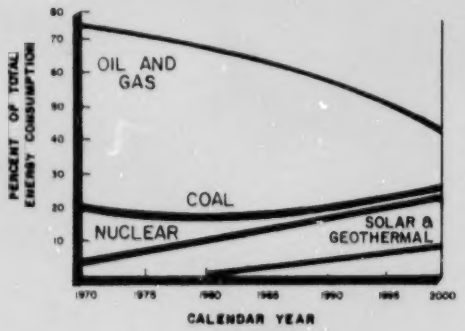
NUCLEAR TECHNOLOGY

Nuclear fission – atom splitting – generates heat, providing an energy source for electrical plants. Its world-wide impact is rapidly increasing. At the beginning of 1980, 67 on-line nuclear-fueled plants provided 13 percent of America's electrical power. By 2000, this percentage will have doubled. And outside the United States, nations on nearly every continent are looking to nuclear fission for electrical power generation.



Projected consumption of various energy sources.

Indeed, nuclear reactors have come of age in the electrical power generating industry. Genuine concerns, embodied in laws and regulations, have required nuclear technology to be among the safest and cleanest processes available for electrical power generation.

Today, nuclear technology, once recognized only for its destructive ability, has become a multipurpose field of endeavor, providing many human services and offering an array of new technical career opportunities.

CAREERS IN NUCLEAR TECHNOLOGY

As a technology, the nuclear field has passed the state of basic research through the phase of applied research and into an era of practical application. The first commercial nuclear electrical power plant (Shippingport, Pennsylvania) came on-line in 1958. But nuclear fission had aready proved its capability as a virtually limitless and inexhaustible power source aboard the submarine, USS Nautilus – this first nuclear powered vessel began its sea trials in 1955. Many of industry's early nuclear operators and technicians were former seamen from the Navy's extensive nuclear fleet.

The world's first nuclear-powered vessel, the USS Nautilus.

Today, a few technical-vocational schools offer limited nuclear programs. But industry's ability to absorb trained technicians with nuclear skills is barely affected by graduates of these programs. Ingress into industry from the Navy has dwindled to an ineffective trickle.

Recent workforce needs assessments, made and supported by a strong National Steering Committee (Appendix A) composed of employers of nuclear operators and technicians, identified a present (1977) need in industry for half a million people with nuclear skills and knowledge. Also, five major technical occupations in or directly related to electrical power plant/nuclear reactor operation were identified:

Radiation Protection Technician.
Nuclear Reactor (Plant) Operator Trainee.
Nuclear Materials Processing Technician.
Quality Assurance/Quality Control Technician.
Nuclear Instrumentation and Control Technician.

The major emphasis of this Guide is preparation of Radiation Protection Technicians. The educational material described herein offers nuclear-option curricula for individuals working with fissionable materials in each of the five technical occupations. Therefore, a general job description of each of these major technician classifications associated with power plants is included, along with a brief mention of other opportunities in nuclear technology.

RADIATION PROTECTION TECHNICIAN

An inherent characteristic of any energy is its potential for doing harm to life and property if allowed to get out of control. This potential existed with the most primitive uses of fire by man, and it exists in the most

Key
- ● Operable
- ○ Under Construction
- □ Limited Work Authorizations
- △ On Order

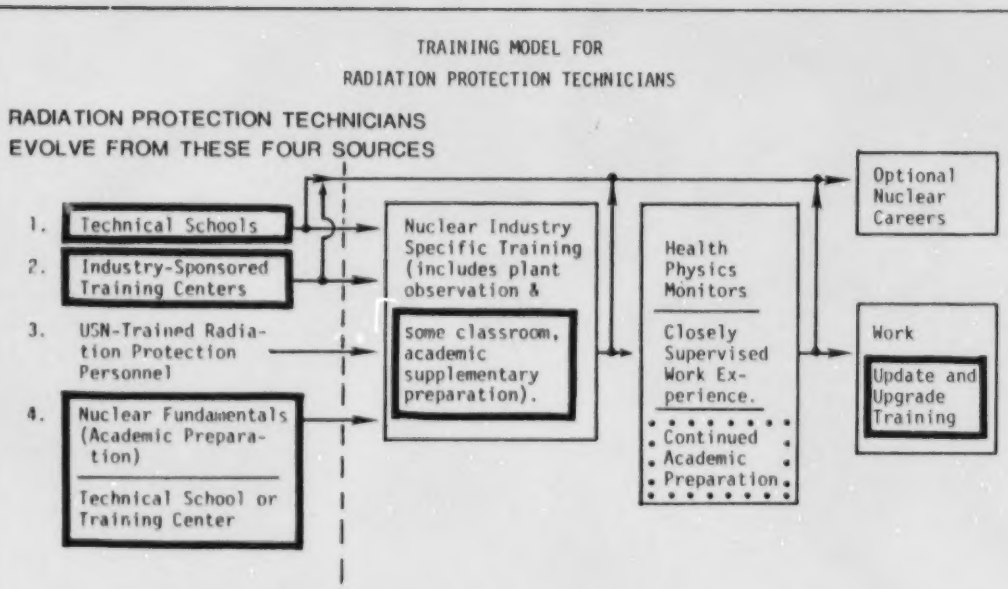
72	Reactors with operating licenses	52,398 MWe
92	Reactors with construction permits	101,148 MWe
4	Reactors with limited work authorizations	4,112 MWe
30	Reactors on order (including 4 units not sited on map)	35,082 MWe
198	Total	192,738 MWe

Nuclear-fired electrical power-plant distribution, December 31, 1978.
(Courtesy U.S. Atomic Forum.)

advanced applications of nuclear fission. Special care must be taken to prevent uncontrolled nuclear radiation. Skilled technicians must monitor and control radiation levels. Radiation protection technicians measure the intensity and identify types of radiation and contamination.

Radiation Protection – protection for employees and the environment.

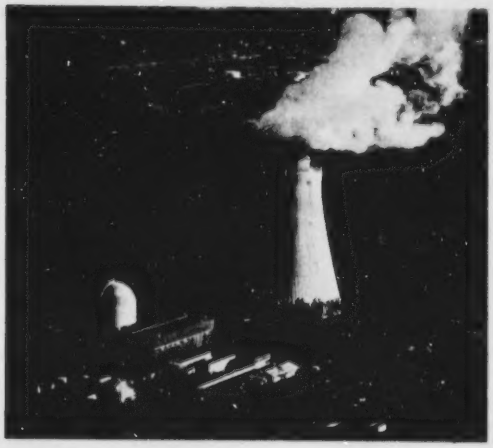
TRAINING MODEL FOR
RADIATION PROTECTION TECHNICIANS


RADIATION PROTECTION TECHNICIANS
EVOLVE FROM THESE FOUR SOURCES
1. Technical Schools
2. Industry-Sponsored Training Centers
3. USN-Trained Radiation Protection Personnel
4. Nuclear Fundamentals (Academic Preparation)
Technical School or Training Center
Nuclear Industry Specific Training (includes plant observation & some classroom, academic supplementary preparation).
Health Physics Monitors
Closely Supervised Work Experience.
Continued Academic Preparation
Optional Nuclear Careers
Work
Update and Upgrade Training

Heavy lines outline areas of academic preparation in which modular curriculum materials described in this Guide may be used effectively. Note the "Optional Nuclear Careers" opportunities as technicians (for those students or trainees electing not to continue work toward Radiation Protection Technicians in the nuclear power industries.

NUCLEAR REACTOR (PLANT) OPERATOR TRAINEE

The nuclear reactor (plant) operator is responsible for proper routine and emergency operation of the facility. This job is the most critical in the plant from the standpoint of responsibility and licensing requirements. Training, experience and performance under stress all figure into the ultimate selection process by which such an operator is licensed by the Nuclear Regulatory Commission (NRC)



Trojan Nuclear Power Plant near Portland, Oregon

and employed by an electric utility. (It has been noted that any shutdown, due to accident or operator error, of an average 1000-MWe power plant can result in a minimum revenue loss equivalent to an operator's salary over a ten-year period. Thus, an operator must combine good judgment with exceptional skill – a combination of learned capabilities best founded on adequate technical education and experience.)

Prior to the late 1970's, nuclear-fueled power plants looked almost exclusively to former Navy reactor operators and technicians as the source of their workforce. These Navy-trained personnel had both an appropriate academic background and a related work experience. With considerable specific facility training and technical retraining a successful transition could be made from the Navy to a utility (power plant).

Other nuclear power plant reactor operators have come from fossil-fueled plants. Operators from such plants, though well versed in general power plant operation, almost always lack nuclear related skills and knowledge. Therefore, they must be given technical preparation as their retraining needs are almost as extensive as those individuals with no related experience.

In recent years, the utilities have established company or contractor training centers, providing curricula that correlate with on-the-job training to prepare individuals having no nuclear academic or work experience to become reactor operators. These training centers have produced the desired results, but at great costs to the utilities – costs that must eventually be borne by the public.

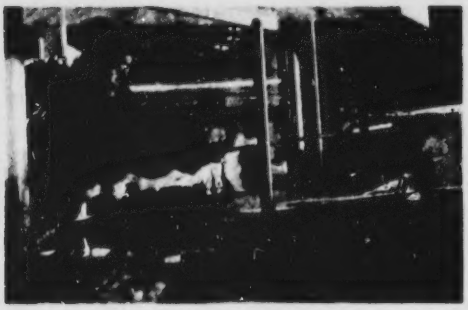
Now, much of the preparation for reactor operator trainees can be provided by post-secondary, two-year, vocational/technical school. The curriculum materials presented in this Guide allow students and trainees to pursue optional careers in nuclear technology.

In addition to nuclear fundamentals, which can be provided by a school, NRC licensing requirements dictate that an operator have experience in the specific plant and on the specialized equipment to be operated. The role of a two-year, post-secondary school program is to prepare nuclear reactor operator trainees who are well grounded in nuclear and power plant fundamentals.

Other technical occupations described briefly in the following paragraphs are plagued with arrays of job titles but, for simplicity, each is limited to its most common formal title.

NUCLEAR MATERIALS PROCESSING TECHNICIAN

This technician performs a variety of tasks related to the milling, conversion, separation and fabrication of nuclear materials and fuels, and may perform tasks related to fuel reprocessing, waste management, radioactive materials and materials irradiation.



Materials handling requires skill and knowledge.

QUALITY ASSURANCE / QUALITY CONTROL TECHNICIAN

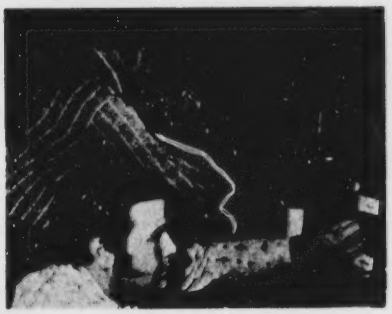
Quality assurance (QA) and quality control (QC) consist of testing, inspecting and auditing materials, equipment and processes to ensure that all are maintained within specified qualitative and quantitative limits.

The QA/QC technician may conduct non-destructive testing of materials or use other methods for inspecting materials and workmanship for compliance with regulations and specifications. Duties may include electrical, civil, mechanical and welding inspection of equipment, materials, processes and structures during construction, operation and maintenance of a power plant.

Trained QA/QC technicians ensure quality materials and workmanship.

NUCLEAR INSTRUMENTATION AND CONTROL TECHNICIAN

Instrumentation has long enjoyed its own "technology." A nuclear instrumentation technician must employ all the skills and knowledge attributable to the basic technology plus those unique to nuclear. Duties include inspection, analysis, calibration, repair, and routine maintenance of instrumentation and control systems (including computer maintenance) throughout the plant.



Calibration, maintenance and repair of nuclear instruments require special training.

OTHER OPPORTUNITIES IN NUCLEAR TECHNOLOGY

In general, the job descriptions indicated above apply to the nuclear power plant workforce – the requirements for nuclear technicians are concentrated in this industry; however, equally challenging and rewarding opportunities exist in the vast support and peripheral industries that supply equipment and materials to the utility companies. Also, nuclear research and medicine utilize technicians in large numbers. Thus, applications of the technology, already widespread, continue to expand.

Support industries, such as nuclear fuel rod fabrication, provide job opportunities.

In general, expanding technological applications indicate an expanding workforce requirement. Certainly, this generality holds true for the nuclear field.

NATIONAL WORKFORCE REQUIREMENTS

Radiation protection personnel are required wherever controls of the hazards of radiation are needed. At this time, with nuclear power plants spanning the nation, it would appear the technical workforce requirements and growth applicable to this Guide are proportional to nuclear power production; therefore, the foreseeable expansion of nuclear power plants may be used as a minimum needs assessment base, to which must be added the substantial workforce demands of other employment areas.

The number of radiation protection personnel needed can be estimated from the figure entitled "Nuclear-fired electrical power plant distribution, December 31, 1979" (page 2). Assuming that each single-unit plant (among those non-licensed, under construction, or on order) requires eight personnel in the radiation protection organization, the bulk of technician needs is given by the following table.

ESTIMATED NUMBER OF RADIATION PROTECTION TECHNICIANS NEEDED IN NUCLEAR POWER PLANTS ALONE.		
1978 – Now	1983	1988
576	+736	+272

This table does not include the additional effects of personnel attrition and increased Regulatory requirements for security and surveillance. This increase of 1000 acceptable trainees over the period of 10 years indicates an annual need of 100 new Radiation Protection Technicians for the nuclear power plant industry alone.

A greater number of radiation protection technicians may be needed in other nuclear areas. These technicians are needed wherever radioactive materials are used; for example, in research, industry, medicine, and agriculture. The demand is growing rapidly.

More technicians will be needed in processing plants, research centers, hospitals and the many other places in which the levels of ionizing radiation must be monitored. Employment of these technicians should expand further as more uses for radioactive materials are developed. Potential employers include the following:

- Nuclear Electric Utilities.
- Nuclear Research Reactor Facilities.
- Nuclear Materials Handling and Processing Facilities.
- Federal and State Regulatory Agencies.

- Nuclear Medicine Units at Larger Hospitals and Clinics.
- Non-Destructive Testing Firms.
- Radio Pharmaceutical Industries.
- Nuclear Waste Handling Facilities.
- Nuclear Service Firms.
- Nuclear Shipyards.
- The National Laboratories.

KNOWLEDGE AND SKILLS REQUIREMENTS FOR RADIATION PROTECTION TECHNICIANS

A significant element of any needs assessment is a determination of the specific skills that graduate technicians must possess to complete those tasks they reasonably might be expected to perform. Sometimes these requirements are referred to as "entry-level skills." These determinations must identify the minimum knowledge and skills a student should acquire prior to graduation.

Although there is no established certification for Radiation Protection Technicians as there is for Nuclear Plant Reactor Operators, a national survey identified the following as a basic list of tasks and required knowledge of personnel employed in the radiation protection areas under any of the following job titles:

- Radiation Protection Technician/ Technologist.
- Health Physics Technician (or Monitor).
- Radiation Control Technician.
- Radiation Monitor.
- Nuclear Spent Fuel Transport Technician.
- Radiation Safety Assistant or Technician.
- Health and Safety Technician.

BASIC LIST OF TASKS & REQUIRED KNOWLEDGE

Monitors personnel, the plant, and the environment for radioactive contamination.

Monitors radiation exposure, both internal and external, to plant workers.

Trains personnel in proper use of monitoring and safety equipment.

Prepares and monitors radioactive waste shipments.

Conducts radiation surveys of the working environment.

Performs basic radiation orientation training, radiation contamination surveys, air sample surveys, and radiation level surveys.

Performs radiation and contamination control surveys.

Performs radiation/protection surveillance for field work parties.

Maintains and calibrates detection instruments against standards to determine accuracy.

Verifies implementation of radiation protection regulations, standards and procedures.

Documents findings and assists with the evaluation of data.

Assists in the preparation of reports.

To meet these requirements, extensive on-the-job experience is essential. To qualify for on-the-job experience, a radiation protection trainee should be well grounded in the fundamentals of nuclear technologies.

Initial preparation of Radiation Protection Technicians is the natural province of two-year, post-secondary schools. Employers have borne the brunt of the training effort in this field until now, but such basic educational programs are at variance with their in-house training role. Thus, assumption of a strong role by schools would be an appropriate move toward proper realignment of nuclear technical education.

Such a move should lift an unnatural burden from industry (pre-entry level training), open new opportunities for successful instructional programs to schools, open new career opportunities to students and add stability to communities in which such schools and industries are situated.

Program requirements – faculty, facilities, equipment, supplies and cost estimates – (discussed in the following section) include classroom-laboratory-office-storage floor space, and a department head with appropriate technical comprehension and industrial experience. Also, such a program calls for a quality curriculum and appropriate instructional materials.

INSTRUCTIONAL PROGRAM

The curriculum described in this section was derived from the task inventory described in the first section.

CURRICULUM

The Radiation Protection Technician Curriculum incorporates learning objectives and supporting objectives based upon related knowledge, as well as upon the tasks the technician is expected to perform in industry today.

Although the curriculum design specifically relates to training Radiation Protection Technicians, every course and every module invites multiple application, as demonstrated in the chart on page 12.

An example of Radiation Protection Technician curriculum is indicated below.

RADIATION PROTECTION TECHNICIAN CURRICULUM

	Periods/Week		
	Class	Lab	Total
First Quarter			
Introduction to Nuclear Technology	2	3	5
* Radiation Physics (Course 1)	3	3	6
Mathematics I	3	2	5
Introduction to Electricity & Electronics	3	3	6
Introduction to Technical Communications	2	2	4
Elective	1	0	1
	14	13	27
Second Quarter			
* Radiation Detection & Measurement (Course 11)	3	4	7
Chemistry I	3	6	9
* Radiation Protection I (Course 2)	3	3	6
Mathematics II	3	2	5
	12	15	27
Third Quarter			
* Introduction to Quality Assurance/Quality Control (Course 14)	2	3	5
* Introduction to Nuclear Systems (Course 5)	3	4	7
Introduction to Radiation Biology	3	3	6
Chemistry II	2	6	8
	10	16	26
Fourth Quarter			
Technical Writing	2	3	5
* Radiation Protection II (Course 17)	3	4	7
* Radiological Emergencies (Course 18)	3	4	7
* Power Plant Chemistry (Course 13)	2	6	8
	10	17	27
Fifth Quarter			
* Radiation Shielding (Course 19)	3	3	6
* Radiation Monitoring Techniques (Course 20)	3	4	7
* Radioactive Materials Disposal and Management (Course 21)	3	4	7
Elective	3	3	6
	12	14	26
Sixth Quarter			
Special Projects	4	8	12
* Advanced Radionuclide Analysis (Course 22)	3	3	6
Occupational Safety and Health	3	3	6
Elective	3	3	6
	13	17	30

* Technical specialty courses for which instructional modules have been developed.

COURSE DESCRIPTIONS

Each course in the curriculum is described to indicate both its content and its relevance to the overall program.

FIRST QUARTER

Introduction to Nuclear Technology.
An introduction to the principles and applications of nuclear energy. Student is introduced to basic principles involved in nuclear radiation, nuclear sources, reactors and fuel cycles. Essential features of a nuclear power plant are discussed. Student also learns how radionuclides and radiation have application in industry and medicine. Nuclear safety will be emphasized and radiation effects evaluated. Lab sessions will include field trips, films and guest speakers. (Note: Materials for this course should be obtained from nuclear utility public relations offices.)

*Radiation Physics.
An introductory course in basic concepts of nuclear radiation. Main topics covered include atomic and nuclear structure, radioactivity and interaction of radiation with matter. Student is introduced to basic radiation and measuring instruments, including Geiger-Müeller counters and personnel monitoring devices.

Mathematics I.
A course in algebra, geometry and introductory trigonometry. Includes ratios, linear equations, plotting, reading and interpreting graphs and sinusoids. Math labs are problem sessions, preferably conducted by the nuclear faculty.

Fundamentals of Electricity and Electronics.
A study of basic principles of direct current and alternating current, series and parallel circuit analyses utilizing Ohm's and Watt's laws, basic motors, generators and relays.

Introduction to Technical Communications.
An introduction to the nature of communication skills and thinking processes with practical exercises in writing, reading, speaking, spelling and vocabulary as related to technical areas. Emphasis on writing, making reports and utilizing the use of a memoranda.

Elective.

SECOND QUARTER

*Radiation Detection and Measurement.
A course in principles and methods used to detect and measure radiation, with emphasis on ionization and scintillation detectors. Statistics of counting will be introduced. Properties of α, β and γ will be studied.

Chemistry I.
Basic chemical principles are introduced, using modern laboratory techniques to demonstrate concepts, including atomic structure of matter, formulae, composition and bonding, the electrical nature of matter, acids, bases, oxides, salts and salt solutions.

*Radiation Protection I.
An introductory course to familiarize student with the field of radiation protection, the art and science of protecting human beings from injury by radiation. Specific topics include dose and exposure measurements and units, biological effects of radiation, Federal Regulations of exposures and internal exposure evaluations.

Mathematics II.
A continuation of Mathematics I; algebra includes logarithms to base 10 and base e and exponentials; geometry and trigonometry emphasizing slopes, rates of change and solutions of equations and problems with transcendental functions.

THIRD QUARTER

*Introduction to Quality Assurance and Quality Control.
An introductory course in quality assurance and quality control; including such topics as history and purpose of quality control, terms and definitions, codes and standards, publications and quality assurance/quality control procedures.

*Introduction to Nuclear Systems.
This course will include a basic understanding of all major components of the reactor core, pressure vessel, shields, and primary cooling water systems. Differences between PWR's and BWR's will be discussed. The basic nuclear fuel cycle also will be discussed.

Introduction to Radiation Biology.
A study of basic biology and radiation damage in biological systems.

Chemistry II.
A continuation of Chemistry I, with more emphasis placed on theory and methods of solution.

*Technical specialty courses.

FOURTH QUARTER

Technical Writing.
A study of effective ways of presenting information with emphasis on the use of logs, keeping of records and notebooks, use of graphs, drawings and sketches, and various types of reports.

*Radiation Protection II.
This course is a continuation of Radiation Protection I and includes calibration techniques for film badges and TLD's; assessment of dose rates obtained from film badges and TLD's; bioassay techniques; and demonstrates proper dose record keeping methods.

*Radiological Emergencies.
This course describes principles of emergency procedures, types of accidents, classifications (including causes and how they are handled), historical cases and planning; detailed procedures for handling a radiological emergency in the laboratory are given. Covering hypothetical conditions; actual exercises for handling radioactive spills in the radiochemistry laboratory; and demonstration of emergency equipment are included.

*Power Plant Chemistry.
A course designed to introduce student to chemistry of fossil and nuclear power plants, including water properties, water treatment and purification, and primary coolant chemistry programs. Gaseous and liquid radioactive waste handling are discussed.

FIFTH QUARTER

*Radiation Shielding.
This course describes the principles of radiation shielding, radiation attenuation, exponential absorption theory, cross-section and absorption coefficients, build-up factors, scattering and material effects; dose reduction of a shield using rule-of-thumb calculations are presented, material, geometry, thickness, radiation type and energy; measured radiation levels in a nearby radiation facility (such as medical x-ray facility) for determination of actual attenuation and scattering effects.

*Radiation Monitoring Techniques.
Description, practices, and familiarity with sample preparation techniques and air, water and biota monitoring techniques for environmental monitoring (both on-site and off-site) of radiation are presented.

*Radioactive Materials Disposal and Management.
Procedures for monitoring and disposal of radioactive materials to conform to DOE, NRC, and DOT regulations; and monitoring and disposition of a given radioactive material sample to conform to the above regulations are described.

Elective.

SIXTH QUARTER

Special Projects.
This course is designed to allow the student to achieve a higher degree of specialization than would otherwise be possible. Work must be on a project closely related to student's chosen specialty. This course should be taken in the last school quarter.

*Advanced Radionuclide Analysis.
This course is designed to allow the student to determine the identity and quantity of an unknown radionuclide from radiation type, energy, half-life and chemical analysis.

Occupational Safety and Health.
General introduction to general occupational safety and health. Specific topics include fire control, general safety and rules and regulations, protective clothing, breathing apparatus, toxicology, and administration of overall safety program.

Elective.

COURSE OPTIONS

As noted previously, almost any nuclear-related training program could utilize material from the model curriculum. Nuclear technology options for these technicians are illustrated in the chart below. Courses 1, 2, 11 and 14 are common to each of the five technology curricula. Numerous other courses are common to two or more of the curricula.

At least two program options or specialties are recommended at schools for several reasons. 1) Radiation Protection job requirements could exclude some students for reasons other than educational non-achievements; i.e., personality traits or handicapped. 2) A temporary shift in workforce requirements may favor an option. 3) Student interest may change after first year of co-op experience.

TECHNICAL COURSES FOR NUCLEAR TECHNOLOGY SERIES

COURSE NO.	TECHNICAL COURSE TITLE	NUMBER OF MODULES	NUCLEAR REACTOR (PLANT) OPERATOR TRAINEE	RADIATION PROTECTION TECHNICIAN	NUCLEAR MATERIALS PROCESSING TECHNICIAN	NUCLEAR QUALITY – ASSURANCE/QUALITY – CONTROL TECHNICIAN	NUCLEAR INSTRUMENTATION AND CONTROL TECHNICIAN
1	Radiation Physics	6	1	1	1	1	1
2	Radiation Protection I	6	2	2	2	2	2
3	Principles of Process Instrumentation	8	3		3	3	3
4	Heat Transfer and Fluid Flow	9*	3				4
5	Introduction to Nuclear Systems	8	4	3		4	4
6	Instrumentation and Control of Reactors and Plant Systems	6	5				5
7	Reactor Operations	7	6				
8	Reactor Safety	5	5				
9	Reactor Auxiliary Systems	4	6				
10	Power Plant Systems	9	5				
11	Radiation Detection and Measurement	8	2	2	2	2	2
12	Reactor Physics	8	4				4
13	Power Plant Chemistry	7	5	4			
14	Introduction to Quality Assurance/ Quality Control	9	3	3	3	3	3
15	Metallurgy and Metals Properties	8	3		4	3	
16	Mechanical Component Characteristics and Specifications	8	4			4	
17	Radiation Protection II	5		4	4		
18	Radiological Emergencies	7		4			
19	Radiation Shielding	6		5			
20	Radiation Monitoring Techniques	7		5	5		
21	Radioactive Materials Disposal and Management	7		5			
22	Advanced Radionuclide Analysis	7		6			
23	Nuclear Chemical Processes	7			5		
24	Nuclear Systems and Safety	6**			6		
25	Radioactive Material Handling Techniques	8***			6		
26	Nondestructive Examination (NDE) Techniques I	7				4	
27	Metrology	8			3	3	
28	Welding Inspection	11				5	
29	Civil/Structural Inspection	8				5	
30	Mechanical Inspection	9				5	
31	Quality Assurance Practices	8				6	
32	Nondestructive Examination (NDE) Techniques II	6				5	
33	Control Systems I	6					5
34	Control Systems II	7					6
35	Power Plant Electrical Systems and Components	7					6

– *Course 4 modified for I&C only. **Module 24.1 is 12.1; 24.2 is 12.2; 24.3 is 12.3. ***Module 25.6 is 21.1; 25.7 is 21.6; 25.8 is 21.4.

NOTE: Numbers in columns denote suggested quarter for use of the courses.

INSTRUCTIONAL MATERIALS

The basis of a sound instructional program is well prepared materials. If scrupulously reviewed by educators and employers, revised and tested, such materials best serve the instructional program, the students and the ultimate employers. The best materials also meet stringent content requirements for flexibility, relevance, currency and validity.

MATERIAL CONTENT AND FORMAT

As noted earlier, nuclear technology encompasses a variety of technical job opportunities with equally great variations in knowledge-and-skills requirements. A curriculum that offers a two-year radiation protection technician program with options for several nuclear-related jobs must be flexible enough to be adapted to specific employer needs on a local basis. Modular materials allow pinpoint selection of appropriate instructional units; for example, the instrumentation technician, whose major involvement is with instruments, with only an incidental involvement in nuclear, should be allowed to select those instructional units applicable to that limited involvement. The flexibility of brief, single-subject, self-contained modules allows a curriculum – whether a seminar, short course, course option or full course – to be custom designed to meet specific needs.

The curriculum material is passed through a variety of critical reviews to ensure its relevancy. Local instructional needs, determined by a local or regional needs assessment and task inventory, make selection of material relevant to local, current needs possible.

Historically, technical instructional materials have evolved slowly. Too often, materials became available at about the same time they became obsolete. To eliminate this problem, the materials described in this Guide are being offered within months – sometimes, weeks – following their initial preparation by authors and reviewers involved in the state-of-the-art technology. Further, through continuing efforts of the National Steering Committee for Nuclear Technician Training, technological advances as well as national employment opportunities are reviewed and relevant data is passed on to institutions and organizations using the material.

The materials are updated as necessary to ensure currency. The most effective manner of ensuring currency, however, is for users of the material to utilize their local industrial advisory committee (IAC) to keep the local program up to the minute on technological changes, variations and workforce requirement fluctuations. (Note: An IAC is described in the following section in detail.)

From the educator's standpoint, educational materials must assume a valid educational format. In this case, the materials are presented in a strictly cognitive form; that is, objectives are stated in "action" terms (perform, calibrate, draw, list, measure), and each module as well as its procedures emphasizes manipulative skills, founded on valid, relevant theory and practice.

Thus, each module, as well as the entire curriculum for radiation protection technicians consists of valid, current, relevant and flexible materials.

MODULE ELEMENTS

Instructional modules developed specifically for this radiation protection technician curriculum contain these basic elements:

Introduction: Identifies topic (and often includes rationale for studying the material).

Module Prerequisites: Identifies knowledge and skills students should possess before studying the module.

Objectives: Clearly identifies what the student is expected to know and do upon completion of module. Objectives are stated in terms of action-oriented behaviors, including such terms as "operate," "measure," "calculate," "identify," and "define," instead of words with many interpretations, such as "know," "understand," "learn," and "appreciate."

Subject Matter: Presents background, theory and techniques supporting the objectives. (Subject matter is written with the technical student in mind.)

Exercises: Provides practical problems to which student can apply new knowledge from module study.

Materials: Identifies equipment required to complete laboratory procedures.

Procedures: Presents experiments or "hands-on" activities, including step-by-step instructions. (Experiments are designed to reinforce student learning.)

Data Tables: Included in most first-year or basic-course modules, the data tables help students learn how to collect and organize data.

Reference Materials: Presents suggestions for supplementary reading.

Test: Measures each student's achievement against objectives stated at the beginning of the module.

Modules average approximately 30 typewritten pages, including illustrations. (Illustrations normally are line drawings that are easily understood and can be reproduced on copy machines for overhead projection.) New modules can be added easily, or existing ones modified, for self-paced instruction or short courses.

A description of the courses and their modules appears in Appendix B. Course and module titles of developed materials (Courses 1-16, 23-35) for the other four curricula are indicated also.

An exhaustive index for each course is scheduled for completion in August, 1980. In addition to this index in the back of each course, a general index to all 35 courses will be available in a separate volume. These indexes will be excellent aids (1) for planners who wish to determine the exact content of each module or course, (2) for students and instructors who must locate materials in the various courses, and (3) for researchers who use the courses as library or plant references.

TRAINING PROGRAM

Planning a training program within an industry differs from institutional planning, in that employer needs dictate program content.

Modular curriculum materials adapt readily to such industrial training programs. Also, they fill the need for less comprehensive short courses and seminars presented by industry or technical associations and intended for updating or upgrading employees.

Module procedures are directed primarily toward students at two-year institutions who have no experience or familiarity with specialized equipment. When an employer uses the instructional modules for employee retraining, the procedures or lab activities should be selectively omitted or replaced.

COOPERATIVE EDUCATION

This technology is adaptable to a cooperative arrangement: a plan which offers important advantages to students, to the school, and to employers of technicians. A cooperative education program provides an opportunity for a student to learn through coordinated study and employment experience. Students alternate periods of attendance at the institution where they study their technical program with periods of supervised employment in business or industry, which provides both training and work experience. The employment constitutes an essential element in their education. The students' employment

should be closely related to the field of study in which they are engaged.

When students test their knowledge of theory in a work situation, study becomes more meaningful. Co-op students learn not only the essentials of the technology but also the importance of reliability, cooperation, and judgment as an employed worker in a chosen occupational field.

Co-op students' career choices are stimulated and strengthened by work experiences. A satisfactory work experience provided in a co-op program assists in stimulating the students' interest and effectiveness in the institutional phase of the program, making it more meaningful. The experience in a co-op program also assists students in knowing if they have made the proper occupational choice prior to completing their educational program and entering employment.

A class of students in cooperative technical programs usually spends the first semester or the first two quarters in school; then time is divided so that half the students have a semester or quarter of employment experience while the other half continues to study. During the next semester or quarter, the half who have worked return to their formal studies at school while the other half are employed. They usually alternate again so that each student has two semesters or at least two quarters of work experience in the program. The students' technical program is lengthened beyond the curriculum outlined in this Guide by an amount of time equal to the total length of the employment experience.

Specific employment is obtained, as circumstances permit, by the educational institution with the cooperation of the student. The institution regards the work-experience program as an integral part of the technician program as a whole. It is not regarded primarily as an opportunity for earning, although each student while working is paid at the prevailing wage scale for the job performed. Work reports by both the student and the employer are submitted to the school work program coordinator.

The cooperative work-experience program is an opportunity for the students to gain directly related experience, which makes them more valuable as employees. As a result of the work-experience in particular establishments, many students are offered permanent positions upon completion of schooling. Cooperating establishments agree, however, not to make offers of employment that become effective before a trainee completes the program.

Cooperative programs provide opportunities for the educational institution to maintain close contact with employers in their various programs. This contact becomes a two-way channel of communication, which helps the educational institution keep its knowledge of specific employer needs in each technical field up to date. At the same time, it keeps employers acquainted with and involved in the institution's program(s).

PLANNING A PROGRAM

Planning should begin with establishment of an advisory committee and a determination of needs, followed by an evaluation of local potential for meeting such needs.* Considerations include:

Faculty.
Student Selection and Services.
Facilities.
Equipment.
Library.
Cost.

The extent and implications of each of these considerations are explored following the discussion of needs.

NEEDS DETERMINATION AND EVALUATION

By using accumulated data and a local industrial advisory committee, a program planner may develop a preliminary local or regional needs determination. The needs determination should consist of a survey documenting: number of existing employers; number of job vacancies; number of expected vacancies in 2, 5 and 10 years; other titles given this same job; job entry specifications; type of need – whether for new employees or retraining of existing employees; and anticipated salary range. A typical survey document is shown in Appendix C.

ADVISORY COMMITTEE

The success of this program depends, to a great extent, on the formal and informal support of an advisory committee. This committee should be appointed by the chief administrative officer of the institution and should be comprised of local (or regional) employers of radiation protection technicians. These members serve without compensation. The committee normally consists of about ten members who should serve from two to three years with staggered terms.

The local advisory committee should assist in studies to determine and define the following: the need for the technical assistant program; the knowledge and skills technicians will require; employment opportunities; available student enrollment; curriculum content; faculty qualifications; laboratory facilities and equipment; resources both within and outside the institution; and, cost and financing of the program. If the survey indicates that a program should be initiated, and will be supported, the committee's help in planning and implementing it is invaluable.

The survey should take a form other than an informal question or two to associates of the committee members. It is suggested that a needs assessment instrument (similar to the one shown in Appendix C) be distributed to employers in the region around the training institution. The form does not have to be elaborate and could be derived from performance objectives stated in this Guide. A checklist of performance objectives, filled out by various employers, gives the school a rather close outline of the knowledge and skills needed by a trainee to be hired in the community.

When the survey instruments are returned to the school, they should be compiled for use in a task inventory for the occupation. A review of the task inventory by the advisory committee is essential at this point. Resurveying at periodic intervals and changing course content accordingly keeps the training program up-to-date and ensures that trainees have a better chance for employment. In today's world of specialized skills and employment, the old concept of curriculum by guess or by past procedure is a disservice to the student and to the training institution.

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*In addition to the "ideas" presented in this Guide to facilitate curriculum planning, members of the project staff and the National Steering Committee are available for consultation and assistance in planning (and implementing) a nuclear program.

The advisory committee should understand that the program is not intended to make individual students proficient in all duties they might be asked to perform at all types of nuclear reactors. Proficiency in highly specialized work comes from experience and further education, or both. It is impossible to accurately predict the rate of change within various work situations. Employers should expect to provide reasonable on-the-job orientation to acquaint the new employee with operational procedures of the facility.

Upon implementation, the committee provides continuing liaison between the institution and employers. Frequently, the committee helps administrators obtain local funds and state and Federal support for the program. The committee also aids in placement of graduates of the program and in evaluating the performance of the graduates on the job. Such evaluations often indicate minor modifications that more closely align the program with employment requirements and opportunities.

The committee should meet as regularly as needed and should keep formal minutes of its proccedings (which could become, in compilation, an annual report of the proceedings). For further elaboration on the role and responsibilities of the advisory committee in technical education programs, refer to Riendeau's Advisory Committees for Occupational Education: A Guide to Organization and Operation.*

This Guide, designed primarily for planning and development of full-time programs in post high school institutions, can be used by the administrator of the institution and an advisory committee as a starting point for development of their own program. It can and should be modified where necessary and adapted to meet local needs and institutional criteria.

*Albert J. Riendeau. Advisory Committees for Occupational Education: A Guide to Organization and Operation. New York: McGraw-Hill, 1977.

FACULTY

The effectiveness of the program and the curriculum depends largely upon the competence and enthusiasm of the teaching staff. With a qualified and interested faculty, a needed educational program may flourish. Qualified faculty members may exist at the institution or withing the industry or organization planning the program, or it may be necessary to recruit a faculty from outside sources. In any event, faculty consideration includes these recommended items:

Numerical Requirements. The number of faculty members needed is based on the duties assigned each member, number of students in the program (first and/or second year) and number of courses scheduled for instruction. The typical teaching load is 18 – 24 class/lab hours per week with the department head assigned not more than 12 hours, allowing time for administrative duties. In the first year, the department head, would be responsible for instruction of 24 students. A full-time instructor would be added in the second year. (See Appendix G for sample costing calculations.)

Competency. The department head should have a strong academic grounding in nuclear technology (BS degree in radiation biology, health physics or equivalent) and suitable experience in industry (e.g., 2 years or more in health physics or related field). An instructor must have sufficient grounding in the technology (as from a well-organized tech school course) must have work experience, and must be a good teacher.

Availability. Qualified personnel must be available within a suitable time frame. (Assistance in identifying faculty requirements and in locating qualified personnel may be obtained from the local industrial advisory committee).

Affordability. The salary structure is a prime consideration. Instructors with experience in the nuclear industry command salaries competitive with industry. An institution must be prepared to pay more for nuclear technology instructors than for welding or mechanic instructors – perhaps even more than some of the deans or campus managers.

Technical programs are designed to produce supportive employees who increase the effectiveness of the total workforce. This principle should be applied to increase the effectiveness of the teaching staff.

Adequate time should be set aside to allow new staff personnel to review the curriculum materials, to visit – if possible – a successful program and its faculty, and to engage in a brief teacher training or familiarization program. The latter program should be designed to ensure that the teacher has an adequate overview of the curriculum materials and a general appreciation of the modular concept. Also, if possible, the teacher should be afforded an opportunity to dialogue with developers of the material, thereby resolving any variances between intended meaning and interpretation.

Staff assistants may be used in stock control to set out the proper equipment for laboratory classes, to keep equipment operating properly, to assist in the development of teaching materials, supervise laboratories, and do a limited amount of routine paper grading and project checking.

By adjusting the size of the supportive staff to the demands of enrollment, a school may partially solve the problem of staffing instructors when it is necessary to teach a number of different courses in one term. Supportive staff members may be recruited from the student body or from graduates of the program.

New approaches to the organization of faculty should be considered. Team teaching is one possible approach. In this sense, team teaching is the organization of a technical staff into a coordinated teaching unit. Teaching assignments are made on the basis of the individual member's special training and talents. Team planning allows for concurrent courses to be closely coordinated by team members to best utilize the student's time while the student is moved smoothly to progressively higher levels.

A weekly departmental staff meeting to encourage and sustain team teaching efforts is recommended. At these meetings, team members can assess and evaluate progress and plan on the basis of this evaluation and on current developments. This is especially important when a new course or a new technique is involved.

In addition to coordinating concurrent courses, staff meetings provide for free exchange of ideas on teaching techniques discovered to be useful and on recently developed laboratory projects which seem to be particularly successful.

To help keep a staff effective, an institution should encourage all staff members to up-date their knowledge of current industrial practice. Their knowledge of teaching techniques and innovations in education must continue to grow and expand. Membership in professional and educational associations should be encouraged, together with active participation in professional association work at local, state, regional and national levels. Through such organizations, faculty can keep up with new literature in the field and maintain closer liaison with employers.

Close contact with employers will also ensure success of the program through the following areas:

Employment of graduates.
Opportunities for cooperative programs.
Assistance in organizing and presenting short courses and conferences.
Donations of equipment and scholarships.
A viable industrial advisory committee.

STUDENT SELECTION AND SERVICES

Preparing functionally competent radiation protection technicians makes three major demands upon the training program: 1) the training should equip graduates to take an entry job in which they will be productive; 2) it should enable graduates to advance to positions of increasing responsibility after a reasonable amount of experience; and 3) it should provide a comprehensive foundation to support further study.

Students entering the program should have certain capabilities, including comprehension and knowledge of underlying subject areas and related skills and adequate study habits and language competencies.

The program described in this Guide is designed for the typical average student (high school graduate or equivalent with one year of math and one basic science course); however, ability levels of those who enter the program generally vary greatly. Many students, whose intelligence and interest make them capable of mastering the curriculum required in the program, have under-developed scholastic skills. If applicants for admission to the program do not have the necessary scholastic background and skills, they should be given an opportunity to enter an organized program for the development of prerequisite skills before entering the technical program. This would ensure them a good probability of successfully completing the technical program. The institution should provide developmental programs to give students this opportunity.

Personal interviews with prospective students for the purpose of effective guidance and counseling are essential. Students should be given interest and aptitude tests by the guidance and counseling departments of the institution to assist them in selecting educational and occupational objectives consistent with their interest and abilities. This will assist them in determining their career objectives and selecting the programs appropriate to their interests.

Students should be given a thorough orientation program upon entry to the institution. This program should include an orientation to the facilities available on the campus, including the student lounges, dining areas, bookstores and recreational facilities. In particular, they should be given a comprehensive tour of the library to familiarize them with its various facilities and procedures and rules governing its use.

Students should be provided information regarding student membership in technical and professional organizations, locally, statewide, and nationally, and encouraged to join such organizations. Membership in professional organizations provides students with an opportunity to receive excellent material on a regular basis at a substantial reduction in cost, to associate with other people in the field at meetings and to develop a habit of regularly reading journal articles to keep their technical knowledge in the field current.

Graduates of the program should be aided in every way in finding suitable employment. Placement of graduates is an important and multifaceted responsibility involving the placement department, the department head and instructurs, and, either directly or indirectly, the advisory committee. However, the primary placement responsibility in new and changing technologies should rest upon the department faculty. They should send out announcements of upcoming graduates to the respondents of the needs survey and to committee members. Outstanding and successfully placed graduates and their employers are the most effective advertisers of the program.

The institution should conduct periodic follow-up studies of graduates to improve curriculum and teaching techniques, evaluate training effectiveness, maintain good employer-

employee relationships, and provide a continuing evaluation of the total program.

FACILITIES

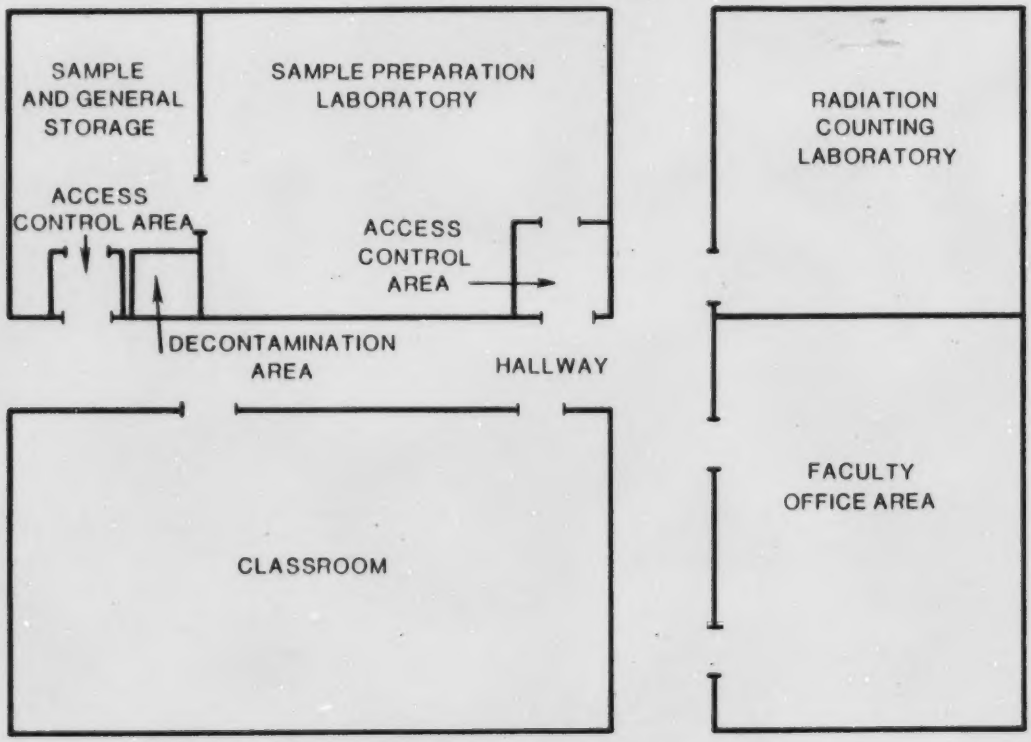
Industrial training programs vary widely according to the need – from classrooms in a plant to sophisticated, specialized training centers; therefore, this discussion applies more specifically to institutional planners whose needs may be standardized to some extent.

For institutions, facility requirements of approximately 2000 square feet include the usual classroom(s), laboratory(ies), storage area(s), and staff office(s). Whenever possible, these areas should be combined in a single building for efficiency, economics and safety.

The following discussion assumes a class size of twenty-four students with two lab sections for each class. Thus, the classroom illustrated accommodates twenty-four to thirty students comfortably. The storage space included is adequate for audio-visual equipment and other materials normally required for classroom instruction.

A typical laboratory layout shown below for implementation of the complete curriculum would include all the elements shown; however, options offered as adjuncts to existing programs may adapt nuclear equipment to electronics of physics laboratories.

Two laboratories should be considered: 1) a general nuclear laboratory with radiation counting capabilities and 2) a sample preparation laboratory; it is necessary to keep counting instruments free from contamination by liquid samples.



SUGGESTED FACILITIES FLOOR PLAN

General laboratory stations should provide ample table area for radiation counting equipment and work space for students' notebooks and charts. Ventilation is important.

Sample preparation laboratory stations should be designed for handling and storing radionuclides and small radioactive sources in a workbench-type layout. Counter tops and sinks (with hot and cold water taps) should be of stainless steel or chrome for easy decontamination and cleaning. Storage drawers should be leadlined. Key-locks should be installed to minimize unauthorized access.

A storage area adjacent to the sample preparation laboratory should include an accountability area for the storage of radioactive materials and contaminants. (Note: A system of accountability provides students with realistic, on-the-job type procedures.) Also, in this area, there should be a workbench and central tool storage.

Staff office space differentiates between department head and instructor(s), and places one person in each office to allow for personalized counseling.

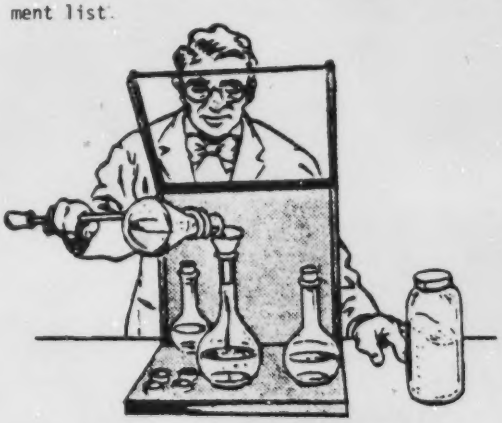
Though new facilities may normally be acquired through established appropriation channels, some schools qualify for various special State and Federal grants. These should be explored by each school's grants department or personnel.

EQUIPMENT

Proper training of technicians for industry entails hands-on experience with industrial-type equipment, insofar as is practical. All unique items of equipment necessary for a viable program in radiation protection training are listed in Appendix E. This list incorporates specific items called out in each module and includes special nuclear laboratory storage and handling equipment.

Each item of equipment is accompanied by a recommended quantity, based on requirements of one class of twenty-four students divided into two laboratory sections of twelve students each. Cost approximations, based on 1979 vendor catalog prices, follow each listing.

The equipment list (Appendix E) includes unique items identified by authors of the curriculum materials as necessary or desired for carrying out procedures included in the modules. (Note: Equipment should be equivalent to that used in industry whenever possible.) Ordering information is included with the equipment list.



Equipment may be either simple or sophisticated.

Not included in the list are such items as visual and audio aids, models and reactor facilities. Such materials are available commercially from industry public relations offices, and government sponsored reactor sharing programs. Usually, access to a research reactor (for institutional training) or a working reactor (for industrial training) can be arranged to permit familiarity with such equipment. A list of university research reactors is found in Appendix D. Also, used equipment and materials can provide excellent teaching aids. In industry-sponsored training programs, such equipment may be obtained from stock; institutions may

need to look to industry – especially their industrial advisory committees – for contributions of used equipment.

LIBRARY

In each module, a list of reference materials is included. For the convenience of each institutional or industrial program developed, a suggested list of references and periodicals is presented in Appendix F.

Dynamic developments, causing rapid changes in technological science and practice make it imperative that a student learn to use a library. Instruction for technology students should include assignments that require them to use the library so that they may form the habit of using the library as a tool in learning. This knowledge helps students develop professional attitudes and further teaches them to depend on libraries to keep abreast of new developements.

Reference materials and related media materials for teaching the technology should be reviewed continuously and revised or replaced, keeping in mind 1) the rapid development of new knowledge, techniques and procedures in the field, 2) the results of research in methodology of teaching in the field of nuclear technology, and 3) the dynamics of change within the structure and philosophy of nuclear industry. It is mandatory that instructors constantly seek and review new references and related media materials as they become available and adopt those that are an improvement over those suggested in this Guide (Appendix F), or those currently in use.

Instructors of all courses should inform their students that library use is an important part of the program. Planned assignments that require the use of a library to research additional facts and new techniques on pertinent subjects enable students to understand the resources available and their relation to technology. Open-book examinations that require use of a library provide excellent objective experiences. Under the incentive of such examination and the pressure of time, students obtain clear understandings of their own competencies in library use.

The growth and success of a graduate technician depend largely on an ability to keep up with changes in the field.

Library content may be classified as basic encyclopedic and reference index material, reference books pertinent to nuclear technology, relevant periodicals and journals, and audio-visual aids.

Therefore, a central library, under the direction of a professional librarian, is important to the success of a technology program. Most instructors have private libraries in their offices from which they may select books of special interest to discuss in their personal conferences with students, thereby stimulating interest in related literuater; however, a central library ensures acquisition and cataloging according to accepted library practices and provides systematic card files, which facilitate the location of reference materials. It also provides a controlled and orderly system for lending books to students, typical of a system they might encounter as employed technicians. Provisions for lending materials for out-of-library use should be systematic and efficient. Suitable study space should be provided students for use of references.

A limited library incorporating books referenced in the curriculum material, supplemented by appropriate specifications (e.g., 10CFR50, ASME Boiler and Pressure Vessel Code, etc.) and relevant trade journals should be maintained in the instructional area.

COST

The information given in Appendix E affords curriculum planners adequate data for estimating equipment costs based on 1979 prices; however, once a tentative equipment list is developed, planners are urged to contact appropriate distributors (from their own associations or from the vendor list provided in Appendix E) and obtain definite price quotes.

Equipment is only one cost that should be predetermined. Facility cost includes the classroom, laboratories, offices and associated areas. It also includes furnishings, utilities and maintenance. In most schools and industrial facilities, these items are determined on a pro-rata basis.

The cost of supplies – used in the offices as well as in the classroom and laboratories, including handouts, preprinted tests and visual aids – should be estimated as accurately as possible.

Faculty and staff costs are a significant item. The costs of field trips and faculty travel and participation in industrial advisory committee meetings, technical associations and their activities, and special seminars should be anticipated.

Making determinations of program costs becomes meaningful when decisions must be made as to 1) whether or not the program is affordable, 2) whether or not the program will be cost effective, and 3) whether or not to implement the program.

To provide the program developer with a rationale for developing cost data, sample calculations are presented in Appendix G. Sample Calculation No. 1 assumes a full class – ongoing program – having department head and a full-time instructor. Calculation No. 2 assumes a typical first-year start-up program: one instructor who also acts as the department head and a minimum number of students. These calculations must not be accepted as accurately reflecting a given situation, but only as guidelines from which a program planner may extract appropriate techniques. Note that all cost estimates (including faculty) attempt to reflect both appropriation and budgetary items (for schools).

The final calculation in Appendix G applies to industry only.

PROGRAM IMPLEMENTATION & EVALUATION

The level of effort involved in implementing a new program of instruction may vary from one setting to another, but the essential elements remain fairly constant.

IMPLEMENTATION

Implementation includes:
- Identifying needs.
- Determining curriculum requirements.
- Preparing and presenting program proposal, obtaining approval.
- Selecting and preparing staff.
- Acquiring facilities and equipment.
- Enlisting students.

LOCAL / REGIONAL NEEDS ASSESSMENT / ANALYSIS

Determination of needs consists of three steps:

Identification of employers:
(both present and potential).
Identification of jobs:
Task inventory.
Entry-level requirements.
Employment projections.
Analysis of Needs:
Benefits versus expenditures.

A listing of employers should be available to interested schools. Local identification of such employers can be achieved readily with the counsel of a well chosen industrial advisory committee, many of whom will be employers (or representatives of employing organizations) of nuclear operators and technicians.

With the assistance of the committee and local employers, the several aspects of job identification can be successfully completed in a relatively brief period of time. Usually, this step can be carried out by mail, utilizing properly prepared survey instruments, examples of which are presented in Appendix C.

Any new program should be self-justifying. The benefits should justify the cost. Factors entering into this analysis include:

Quantity of job opportunities.
Quality of job opportunities.
Projected job opportunities.
Capability of instruction to offer program:
- Budget.
- Facilities.
- Faculty.
- Administrative fervor.
  (Without an administrative commitment, no program is apt to evolve, even though all other elements are present.)

The industrial advisory committee's expertise should be utilized in this analysis of needs. Each member should be given an opportunity to review and evaluate the cumulative results of the needs survey and the school representative's assessment of the institution's capabilities. They may be able to suggest or propose ways of overcoming certain weaknesses or shortcomings.

CURRICULUM REQUIREMENTS DETERMINATION

Because curricula must be responsive (in technical education) to the real needs of technological industry, any determination of curriculum requirements must come after a realistic assessment and analysis of industrial workforce needs. The modular curriculum suggested in this Guide for training nuclear operators and technicians can be adopted wholly or in part to meet the real needs of industry. The materials to be used should be selected with care and, preferably, with the consultation of committee members to ensure compatability with industrial needs.

Personnel, familiar with the material's content and sequencing and experienced in the matching of the curriculum to needs, should be utilized in developing the program. Members of the industrial advisory committee, with knowledge of workforce training needs, should assist in the reviewing and selecting process.

Technical education must meet industry needs.

Once program implementation reaches this development point, a formal proposal – in most institutions – must be prepared and presented to appropriate administrators, boards and agencies.

PROGRAM PROPOSAL PREPARATION

Three criteria should be satisfied in presenting a successful proposal for a new technical education program.

Need (for program). This criteria should have been established by the needs assessment and analysis. All data, both supportive and detractive, should be included along with letters or directly quoted comments and opinions of industrial advisory committee members.

Capability (of institution to provide program). This criteria includes: 1) fair and comprehensive evaluation of a school's interest in the program (top executives and/or administrative support and faculty enthusiasm), 2) its budgetary potential (requires a good estimate of program's cost and enrollment potential), and 3) its available facilities.

Cost effectiveness. There are two approaches to this determination: 1) immediate effectiveness – whenever possible, a program should be self-sustaining. Thus, it is important to establish program cost versus direct economic return. All the inputs that go into making this determination, including a realistic projection of enrollment in the program, should be incorporated into this proposal; 2) long-term effectiveness – total effect of the program on school resources should be weighed against benefits to society. In many instances, these determinants must be stated in intangible terms. Even so, they should be presented fairly and as accurately as possible.

PROPOSAL FORMAT

The format of the proposal varies extensively from school to school; however, as a general rule any proposal should be as straightforward, concise and simply stated as its preparer can make it. The following elements are meant only to imply a possible outline.

Preface. (What the document is: who prepared it; for whom was it prepared?) No more than one (1) page.

The Need. Reflecting all items discussed earlier.

The Curriculum.

The Plan. Organizational approach; facilities utilization; human and financial resources.

The Cost.

The Benefits.

The Recommendations. Based on reasonably drawn conclusions.

Letters/documents of support.

Evaluation of existing compatible programs.

Once a program has received formal approval, instructional preparation becomes an immediate consideration.

EVALUATION

Human endeavor is subject to continual evaluation, generally informal, but evaluation nonetheless. It is this ongoing monitor-review activity that guides any individual or corporate activity to ultimate success – success that can only be assessed in retrospect. An educational program – human endeavor of a corporate nature – should also be evaluated progressively (as well as on the basis of its end product) to ensure its constancy toward the development of a successful end product.

CURRICULUM ACCEPTANCE

While a major evaluation factor is adequate enrollment, other criteria provide significant, if not major, evaluation tools:

Drawing power and holding power of program. Does program attract and hold qualified students in a manner comparable with similar technical programs?

Student enthusiasm and morale. Is there an observable esprit de corps within the classes or groups of students enrolled in the program?

Enrollment figures (compared with similar technical programs or with enrollment goals or limitations) answer the first question. The second may require a more comprehensive evaluation. For example, student response to a program may be evaluated subjectively by adjudging such factors as:

Interest/disinterest in classroom activities, laboratory procedures and homework or outside study (based on attentiveness and actions).

Enthusiasm/indifference as related to the total program (based on attendance).

Test scores on materials that judge student's progress in assimilating skills and knowledge essential for technical employment.

More commonly, however, evaluation tools are employed to reflect the students' responses more directly. This objective evaluation procedure (from the faculty's standpoint), which employs one or more questionnaires, seeks responses in the following areas:

Teacher effectiveness (including lab instructors).

Materials applicability (including understandability and program content relevance).

Facilities and equipment adequacy.

Student self-evaluation (including attitude, progress and continued interest).

GRADUATE PERFORMANCE

The ultimate evaluation of a technical education program stems from the success of its graduates:

Do their skills and knowledge meet entry-level requirements?

Are they successful in the job market?

Does their on-the-job performance satisfy employer expectations?

Are they promotable?

These questions may be asked of both the graduates and their employers. (Placement records may be more indicative of a hungry job market than a successful training program; therefore, evaluation should go beyond this initial transition from student to employee).

Graduated students, along with their employers, should also be asked to reflect upon or review the training program periodically. This means of relating program content to occupational needs should prove especially valuable in incorporating new or updating technological developments into the program.

APPENDICES

APPENDIX A

NATIONAL STEERING COMMITTEE FOR NUCLEAR TECHNICIAN TRAINING

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APPENDIX B

TECHNICAL SPECIALTY COURSES AND MODULE TITLES AND DESCRIPTIONS

COURSE 1, RADIATION PHYSICS.

Module 1-1, "Introduction to Radiation Laboratory Safety."

This module examines basic radiation safety terms including: radioactivity, radiation, agreement state, monitoring radioactive waste and decontamination. Guidelines are also given which provide a method for developing specific laboratory rules relating to radiation safety.

Module 1-2, "Basic Radiation Detection and Measuring Equipment."

Included in this module is a description and discussion of the function of (a) ionization, (b) film badge, (c) dosimeter, (d) scaler, (e) ratemeter and (f) count-rate.

Module 1-3, "Atomic Structure and Radioactivity."

This module includes basic principles of atomic structure, definition of elements and atoms, and a description of the Geiger-Mueller plateau. Each topic is illustrated with labeled diagrams.

Module 1-4, "Radioactive Decay and Half-Life."

Radioactive decay and half-life are described through the definition of (a) radioactive decay, (b) stability, (c) nuclear force, (d) electrostatic force, (e) half-life, (f) decay constant, (g) activity, (h) specific activity, (i) Avogadro's number, (j) curie, (k) nucleon, (l) gram-atomic weight and (m) atomic weight.

Module 1-5, "Radioactive Decay Processes and Schemes."

Several aspects of particulate radiation are described including particle speed, mass in AMU, electrical charge and penetrability. Sample decay equations and decay schemes for given decay processes are illustrated. Instructions are also given for reading and interpreting the Chart of Nuclides.

Module 1-6, "Basic Properties of Gamma Radiation."

This module includes a basic description of gamma radiation and its properties.

COURSE 2, RADIATION PROTECTION I.

Module 2-1, "Radiation Exposure and Absorbed Dose Values."

This material involves a study of radiation exposure and absorbed dose values by defining the limits of usage for the units of radiation dosage, teaching rapid conversion from all systems of units into rem and explaining why quality factor is different for different types of radiation.

Module 2-2, "Biological Effects of Radiation."

The biological effects of radiation including: mechanisms by which radiation damages living body cells, typical radiation syndrome, differentiation between internal and external radiation exposures are presented. Also included is a discussion and evaluation of the hazards of biological injury to the general population versus that to the radiation worker and an explanation of the benefit versus risk concept in the use of radiation.

Module 2-3, "Radiation Protection Standards."

Initially this module examines the radiation protection standards associated with dose level exposures for accumulated whole body, extremities and skin. The correct completion of all application and report forms required by state and local standards pertinent to radiation protection and establishment and maintenance of record systems that facilitate compliance with the regulations are also included.

Module 2-4, "Internal Dose Calculations."

Various methods of internal dose calculations are discussed including: MPC, body burden, standard man, bioassay, ICRP, critical organ, handbook 69, effective half-life, empirical, smear, RBE, radiosensitivity, ash sample, on-short intake.

Module 2-5, "Personnel Monitoring Devices, Ionization Types."

This module contains a detailed look at the ionizing type personnel monitoring devices. The two common types of dosimeters are illustrated, their structure examined, and the mechanism for charging and reading the dosimeter is discussed. The precautions and limitations to be observed in using dosimeters are also listed.

Module 2-6, "Personnel Monitoring Devices, Chemical Types."

Chemical types of personnel monitoring devices are looked at in detail. Five different types are examined as to their ability to detect ionizing and neutron radiation, basic operational feature, relative accuracy and speed of use. Guidelines are also provided for the selection of the most practical types to be utilized under given radiation monitoring situations.

COURSE 5, INTRODUCTION TO NUCLEAR SYSTEMS.

Module 5-1, "Basic Nuclear Reactor Components."

Sketches and diagrams are used to illustrate and discuss the components of a light water reactor, reactor vessels, control rod drive systems (PWR and BWR) and assemblies in PWR and BWR systems.

Module 5-2, "Pressurized Water Reactor (PWR)."

This module gives a detailed look at a pressurized water reactor (PWR) including the hydraulic, pneumatic and electrical components. Diagrams and illustrations show their internal structures, and the two basic types of steam generators are illustrated and discussed.

Module 5-3, "Boiling Water Reactor (BWR)."

The boiling water reactor (BWR) is described in detail including its advantages and limitations. Illustrations clearly describe the various systems and components of the BWR. Fuel assemblies, control rods and jet pumps are also described in detail.

Module 5-4, "Primary Cooling Systems."

A brief review of the reactor vessel, pressurizers and steam generators is provided. Detailed mechanisms and design characteristics of reactor coolant pumps, piping, primary systems, valves and insulation also are shown. Overall design specifications and in-service inspection also are discussed.

Module 5-5, "Nuclear Instrumentation."

This module describes in detail the types and components of radiation detectors used to monitor radiation levels in power plants. Four kinds of radiation and associated instruments are listed and discussed as well as back up or fail safe systems for monitors.

Module 5-6, "Nuclear Fuel Cycle."

The complete nuclear fuel cycle is illustrated and described in detail through the following steps: (a) mining, (b) milling, (c) refining, (d) enriching, (e) oxide fabrication and (f) fuel assembly through reprocessing spent fuel. Plutonium and thorium are also introduced as potential fuels for the future. A visit to a plant involved in one of the steps in the cycle is encouraged.

COURSE 11, RADIATION DETECTION AND MEASUREMENT.

Module 11-1, "Statistics of Radiation Counting."

Radioactivity follows certain predictable patterns which are statistically described through the definitions of (a) radioactive decay, (b) geometry factor, (c) interactions, (d) inverse-square law, (e) dead time, (f) average value, (g) standard error, (h) theoretical standard deviation, (i) standard deviation, and (j) normal distribution. Background radiation and changes in counter geometry are also discussed.

Module 11-2, "Gas-Filled Detectors I: Ionization Detectors."

Three types of ionization detectors including the integrating, nonintegrating and mean-level are described. The module also describes the calculation of current produced by given exposure, ionization chambers and curves, and the details of a pocket dosimeter. Other items defined in the module include: (a) pulse counter, (b) ion pair, (c) recombination, (d) saturation voltage, (e) saturation current, (f) discriminator, (g) air equivalence, (h) energy dependence, (i) spectroscopy, and (j) efficiency.

Module 11-3, "Gas-Filled Detectors II: Proportional Counters."

This is the second module in a series discussing detectors and describes proportional counters — the five basic types and varieties. Definitions found in the module include: (a) P-10 gas, (b) internal proportional counter, (c) 4π or absolute counter, (d) flow-through counter, (e) discriminator, (f) resolving time, (g) fission counter, (h) proton recoil counter, (i) Hurst counter, and (j) Hurst dosimeter.

Module 11-4, "Gas-Filled Detectors III: Geiger-MÜeller Counters."

This is the third module in the detector series and specifically describes the operating mechanisms of a gas-filled detector using the Geiger counter as an example. Terms discussed and defined include: (a) internal and external quenching, (b) limited proportionality, (c) break-down voltage, (d) continuous-discharge region, (e) multiple discharge, (f) dead time, (g) recovery time, (h) geometry factor, and (i) self-absorption.

Module 11-5, "Scintillators, Semiconductors and Spectroscopy."

Another class of detectors includes the solid-state devices discussed in this module including the four basic types of scintillation counters and the three categories of semiconductor devices. Also covered are such terms as: (a) photomultiplier tube, (b) luminescence, (c) phosphorescence, (d) activator, (e) photocathode, (f) dynodes, (g) secondary emission ratio, (h) well crystal, (i) p-n junction, (j) depletion layer, (k) GeLi detector, and (l) pulse-height analysis.

Module 11-6, "External Personnel Dosimeters for Beta-Photon Monitoring."

Two major types of dosimeters (namely, photographic and luminescent dosimeters) are discussed and illustrated including the mechanisms for calibration, limitations, and optimum use. Several other items are described including: (a) roentgen, (b) rad, (c) rem, (d) quality factor, (e) latent image, (f) sensitivity, (g) energy dependence, (h) radiophotoluminescence, (i) thermoluminescence, (j) glow curve, and (k) glow peak. The effect of radiation dose is also briefly discussed.

Module 11-7, "Neutron Detectors, Dosimetry and Activation Analysis."

Three major groupings of neutron detectors and their applications are described and the details of a compensated ionization chamber, activation foils, the albedo neutron dosimeter and a fission-fragment dosimeter are included. Neutron activation analysis is also introduced and briefly described.

Module 11-8, "Radiological Calibration and Standardization."

This module examines five aspects of radioactive standardization including: (a) measurement of disintegration rate, (b) mass determination, (c) calorimeter, (d) source preparation, and (e) standardized solutions used. Common radioactive standardization sources are discussed and requirements of the National Bureau of Standards also are outlined.

COURSE 13, POWER PLANT CHEMISTRY.

Module 13-1, "Water Quality Control."

Three basic topics are covered in this module starting with sources of water and initial treatment, to specific preparation of reactor makeup water and finally the equipment used to monitor its quality. Several of the impurities and their potential effect on the function of the system are also given in detail.

Module 13-2, "Raw Water Treatment."

The five most common water contaminants including color, suspended and dissolved solids, gases, odors and algae are discussed and the methods of treatment (coagulation, filtration, chlorination and de-aeration) are described.

Module 13-3, "Sources of Impurities in Reactor Water Systems."

An initial look at the consequences of scale formation is provided in this module. Common forms of metal corrosion and sources of reactor impurities including metal corrosion, activation products and fission products are described.

Module 13-4, "Water Treatment - Polishing by Ion Exchange, Evaporation and Demineralization."

Water treatment processes such as ion exchange and demineralization are explained both in theory and actual processs during this module. Types most commonly used in PWR's and BWR's are identified and illustrated.

Module 13-5, "Water Properties Sensing."

Specific examples of devices used to monitor pH, conductivity, dissolved oxygen, halide ions and turbidity are presented in this module, and their location in the primary and condensate feedwater systems of PWR's and BWR's is described.

Module 13-6, "Water Analysis for Nuclear Power Plants."

This module examines the various water sampling techniques that are not of a continuous nature but are used to monitor less critical impurities. Frequency of these tests, methods and instruments used to establish their level and their significance in the reactor system are also defined.

Module 13-7, "Radioactive Waste Handling - Liquid and Gaseous."

The sources of gaseous and liquid wastes in BWR's and PWR's and the treatment of these wastes is covered in detail. Summary of the Federal Regulations concerning the disposal of radioactive gases, liquids and solids is also reviewed.

COURSE 14, INTRODUCTION TO QUALITY ASSURANCE/QUALITY CONTROL.

Module 14-1, "Basic Requirements for Quality Assurance/Quality Control in the Nuclear Industry."

This module introduces the topic of QA/QC through a description of: (a) Federal regulatory processes, (b) an overview of QA/QC, (c) other participants in the licensing process, (d) the impact of technical professional organizations on QA/QC, and (e) a listing of the self-regulating mechanisms of the industry.

Module 14-2, "Definitions and Descriptions of Quality Assurance/Quality Control Criteria."

A concise definition of quality assurance and quality control and their differences are given in this module. The meanings of each of the eighteen QA criteria and basic duties of QA/QC personnel are also provided.

Module 14-3, "Governmental Regulation of Quality Assurance/Quality Control (AEC, NRC)."

The historical evolution of the AEC and NRC and their impact on nuclear regulation includes a discussion of Federal Regulation 10CFR50. Also included in this module is a description of the NRC rainbow-colored books which discuss various aspects of QA/QC. Finally, a brief description of the NRC regulatory guides is provided.

Module 14-4, "Technical Regulation of Quality Assurance/Quality Control (ASME, ANSI)."

Section III of the ASME code is examined in detail as is ANSI standard N45-2. The influence of ASTM, IEEE, ACI and AWS on QA/QC is also given.

Module 14-5, "Implementation of Quality Assurance/Quality Control Programs and Procedures."

The parts of the QA/QC manual are described including minimum standards. A method of devising procedures and instruction documents and the contents of the ten parts is also provided. Finally, a note as to the functions of the QA/QC personnel is documented.

Module 14-6, "Application of Quality Assurance/Quality Control to Industry."

This module specifies the five requirements of 10CFR50, ASME code and ANSI standards for quality assurance/quality control which affect: (a) design aspects of materials, components and facilities, (b) manufacturing processes, (c) construction, testing and inspection, and (d) operation and maintenance for nuclear facilities.

Module 14-7, "Techniques and Variations in Quality Assurance/Quality Control."

Three QA/QC establishment procedures are described including user developed, consultant assisted and subcontracted programs. Example forms are provided as indicators of typical tag sheets for QA/QC monitoring.

Module 14-8, "Quality Assurance/Quality Control Records and Documents."

Verification of QA/QC activities is handled through accurate, timely documentation of forms shown in this module. Selection of mechanisms for indexing, storage and retrieval of permanent and nonpermanent records through the record control center is also discussed.

Module 14-9, "Special Studies in Quality Assurance/Quality Control."

General QA/QC requirements for technical and quality-assurance specifications are described. Several aspects of QA/QC personnel including: (a) certification, (b) on-the-job training, and (c) seminars, indoctrination programs, and orientations are also outlined. Briefly identified also are six methods of inspections, tests and verifications.

COURSE 17, RADIATION PROTECTION II.

Module 17-1, "Film Dosimetry."

Upon completion of this module, the student should be able to use film badges for determination of beta, gamma, x-ray and neutron doses, evaluate the exposure results, describe techniques used to evaluate, calibrate and develop films.

Module 17-2, "Thermoluminescent Dosimetry (TLD)."

Upon completion of this module, the student should be able to calibrate and process TLD's for beta, gamma, x-ray and neutron doses.

Module 17-3, "Radiation Dose Assessment."

Upon completion of this module, the student should be able to assess the external radiation dose read by film badges and TLD's and relate to recommended exposure dose limits.

Module 17-4, "Internal Dose Assessment."

Upon completion of this module, the student should be able to describe how radioactive materials enter the body and how they are metabolized there. The student should be able to perform internal dose calculations.

Module 17-5, "Bioassay Techniques and Recordkeeping for Radiation Protection."

Upon completion of this module, the student should be able to describe procedures and equipment used, how to determine a representative sample, how to choose the correct equipment, how to choose the correct sample preparation technique, and how to analyze the result for bioassay monitoring; and perform an actual bioassay, including the choosing of the appropriate equipment and sample preparation technique, and analysis of the sample to determine the concentration. The student should be able to described the various types of radiation records kept in a nuclear facility; explain the reasons (including legal) why these records must be kept; and devise a recordkeeping system for a small radiation laboratory, including the types and frequency of data collection.

COURSE 18, RADIOLOGICAL EMERGENCIES.

Module 18-1, "General Procedures for Radiological Emergencies."

Upon completion of this module, the student should be able to describe principles of emergency procedures, general classifications (including causes and how they are handled), types of accidents, and historical cases.

Module 18-2, "Emergency Equipment for Nuclear Facilities."

Upon completion of this module, the student should be able to demonstrate the use of, and to give the applicability of, the following emergency equipment: rescue equipment, protective clothing, breathing apparatus, and emergency monitoring instruments.

Module 18-3, "Surface Contamination – Decontamination."

Upon completion of this module, the student should be able to describe types and characteristics of surface contamination, control and evaluation of contamination, effects of surface finishes, principles and objectives of decontamination, and procedures and equipment for decontamination.

Module 18-4, "Criticality Control."

Upon completion of this module, the student should be able to discuss general principles and theoretical aspects, safe designs, safety instrumentation, and operational requirements for criticality control; and discuss practical aspects of criticality control in research and power reactors, fuel production and processing, and transportation and storage of fissionable materials.

Module 18-5, "Control of Radiological Hazards."

Upon completion of this module, the student should be able to discuss methods by which radioactivity that results from radiological emergencies can enter the environment, through atmospheric dispersion and disposition, inland and sea waters, geological structures, and other media.

Module 18-6, "Emergency Planning for Nuclear Facilities."

Upon completion of this module, the student should be able to describe the overall emergency planning of a nuclear facility, including actions and responsibilities of various groups, emergency equipment, emergency drills, post-accident activities and cleanups, and exposure assessment.

Module 18-7, "Emergency Drills for Nuclear Facilities."

Upon completion of this module, the student should be able to participate in an emergency drill of a simulated, large radioactivity release in a nuclear facility or radiation laboratory and to demonstrate proper and/or correct knowledge of the following: evaluation and assessment, evacuation, use of emergency equipment, equipment shutdown, decontamination, and re-entry.

COURSE 19, RADIATION SHIELDING.

Module 19-1, "General Effect of Radiation Attenuation."

Upon completion of this module, the student should be able to describe the effect of radiation type, energy, scattering, and shield material on radiation attenuation.

Module 19-2, "Beta and Alpha Particle Attenuation."

Upon completion of this module, the student should be able to describe the effect of energy, scattering, and shield material on beta and alpha radiation attenuation; and to calculate the attenuation of alpha and beta radiation through a shield, given the radiation type, energy, shield dimensions, and material.

Module 19-3, "Neutron Attenuation."

Upon completion of this module, the student should be able to describe the effect of the energy, scattering, and shield material on neutron radiation attenuation; to calculate the attenuation of a neutron beam through a shield, given the energy, shield dimensions, and material; to describe the meaning of scattering and absorption cross section, both microscopic and macroscopic; and to calculate the macroscopic cross section, given the absorbing material and neutron energy.

Module 19-4, "Gamma Attenuation."

Upon completion of this module, the student should be able to describe the effect of energy, scattering, and shield material on gamma-radiation attenuation; and to calculate the attenuation of gamma radiation through a shield, given the energy, shield dimensions, and material.

Module 19-5, "Background Radiation Reduction Techniques."

Upon completion of this module, the student should be able to discuss the reasons for, and precautions necessary to, the accurate performance of low-background measurements.

Module 19-6, "Backscattering and Wall Scattering of Radiation."

Upon completion of this module, the student should be able to describe the effect of backscattering and wall scattering on beta, gamma, and neutron radiation; to measure radiation levels in a nearby radiation facility (such as a medical x-ray facility); to determine actual attenuation and scattering effects.

COURSE 20, RADIATION MONITORING TECHNIQUES.

Module 20-1, "Radiation Sample Preparation – Liquid."

Upon completion of this module, the student should be able to describe various methods for preparation and counting of a liquid sample for radioactive measurements; practice preparing and counting the samples; and obtain familiarity with micro-measuring techniques and with remote handling techniques.

Module 20-2, "Radiation Sample Preparation – Solid."

Upon completion of this module, the student should be able to describe various methods for preparing and counting a solid sample for radioactive measurements; practice preparing and counting the samples, and obtain familiarity with micro-measuring techniques and with remote handling techniques.

Module 20-3, "Air Monitoring Techniques – Particulate."

Upon completion of this module, the student should be able to describe procedures and equipment used to gather a representative sample, how to choose a sampler, and how to analyze a filter sample for monitoring air containing particulate radioactivity; and perform such actual air monitoring, including choosing the appropriate samplers, assuring a representative sample and analyzing the sample to determine the atmospheric concentration.

Module 20-4, "Air Monitoring Techniques – Gaseous."

Upon completion of this module, the student should be able to describe procedures and equipment used, how to gather a representative sample, how to choose a sampler, and how to analyze a filter sample for monitoring air containing gaseous radioactivity; and perform such actual air monitoring, including choosing the appropriate samplers, assuring a representative sample and analyzing the sample to determine the atmospheric concentration.

Module 20-5, "Water Monitoring Techniques – Dissolved Solids."

Upon completion of this module, the student should be able to described procedures and equipment used, how to gather a representative sample, how to choose the correct equipment, how to choose the correct sample preparation technique, and how to analyze the result for the monitoring of water that contains dissolved solid radioactivity; and perform such an actual monitoring, including the choice of appropriate equipment and sample preparation techniques and analysis of the sample to determine the concentration.

Module 20-6, "Water Monitoring Techniques – Suspended Solids."

Upon completion of this module, the student should be able to describe procedures and equipment used, how to gather a representative sample, how to choose the correct equipment, how to choose the correct sample preparation technique, and how to analyze the result for monitoring water that contains suspended solid radioactivity; and perform such an actual monitoring, including the choice of the appropriate equipment and sample preparation technique and analysis of the sample to determine the concentration.

Module 20-7, "Radiation Monitoring of Biological Samples."

Upon completion of this module, the student should be able to describe procedures and equipment used, how to gather a representative sample, how to choose the correct equipment, how to choose the correct sample preparation technique, and how to analyze the result of the monitoring of biota (fish, animals, soil, and plants); and perform such actual monitoring, including the choice of the appropriate equipment and sample preparation technique and analysis of the sample to determine the concentration.

COURSE 21, RADIOACTIVE MATERIALS DISPOSAL AND MANAGEMENT.

Module 21-1, "Waste Disposal Procedures."

Upon completion of this module, the student should be able to discuss sources of radioactive waste in a nuclear power plant; to describe procedures for disposing radioactive materials from a laboratory and from a nuclear power plant; and to cite procedures for disposing of a given radioactive material in the laboratory.

Module 21-2, "Routine Sampling of Radioactive Waste."

Upon completion of this module, the student should be able to describe radioactive waste processing and disposal systems in nuclear facilities and the hazards associated therewith; to draw a typical schematic diagram of a system, showing sampling locations; and to describe the techniques used to sample and analyze the systems.

Module 21-3, "Waste Disposal Regulations."

Upon completion of this module, the student should be able to discuss the limits placed on discharge of radioactive waste by DOE, NRC, and various state and local agencies. The student also should be able to classify the various types of waste and to describe methods used in the analysis of each.

Module 21-4, "Measurement of External Radioactive Contamination."

Upon completion of this module, the student should be able to describe the necessary steps in taking a sample for the testing of the exterior surface of a shipping or storage container of nuclear material.

Module 21-5, "Regulations for Transporting Radioactive Materials."

Upon completion of this module, the student should be able to discuss the DOT requirements for shipping radioactive materials; to discuss types of accidents that could occur during shipping and the consequences of each; and to discuss steps that would be taken following such accidents.

Module 21-6, "Packaging and Monitoring of Radioactive Materials for Shipment."

Upon completion of this module, the student should be able to describe procedures for monitoring shipments of radioactive material sent off-site, including compliance with NRC and state regulations.

Module 21-7, "Leak Tests of Sealed Radioactive Sources."

Upon completion of this module, the student should be able to test the integrity of a sealed source and to discuss the process used to seal sources.

COURSE 22, ADVANCED RADIONUCLIDE ANALYSIS.

Module 22-1, "Survey of Methods Used in Radionuclide Analysis (Sample Collection and Analysis)."

Upon completion of this module, the student should be able to describe briefly the various techniques and equipment used to identify unknown radionuclides and how to choose the correct technique and equipment for a given unknown.

Module 22-2, "Gamma Spectrometry."

Upon completion of this module, the student should be able to described gamma spectrometry techniques for the identification of unknown radionuclides and to perform a radionuclide determination by gamma spectrometry.

Module 22-3, "Alpha Spectrometry."

Upon completion of this module, the student should be able to describe alpha spectrometry techniques for the identification of unknown radionuclides and to perform a radionuclide determination by using alpha spectrometry.

Module 22-4, "Beta Spectrometry."

Upon completion of this module, the student should be able to describe beta spectrometry techniques for the identification of unknown radionuclides and to perform a radionuclide determination by beta spectrometry.

Module 22-5, "Radiochemical Methods of Analysis by Liquid Scintillation Counting."

Upon completion of this module, the student should be able to describe several radiochemical methods, used either alone or in conjunction with a radiation-spectrometry method, to determine the identity of radionuclides, and to perform an actual radionuclide determination by a radiochemical method.

Module 22-6, "Neutron Activation Analysis."

Upon completion of this module, the student should be able to describe procedures for neutron activation analysis, and to perform an actual neutron activation analysis.

Module 22-7, "Determination of Specific Nuclides."

Upon completion of this module, the student should be able to determine the identity of unknown radionuclides by use of the appropriate procedures and equipment.

Courses being developed for the other curricula in the Nuclear Technology series (see chart on page 12) follow:

COURSE 3: PRINCIPLES OF PROCESS INSTRUMENTATION.

Module 3-1: Temperature-Sensing Devices: Glass-Bulb Thermometers.
Module 3-2: Temperature-Sensing Devices: Thermocouples.
Module 3-3: Temperature-Sensing Devices: Resistance Thermometers.
Module 3-4: Temperature-Sensing Devices: Pyrometers.
Module 3-5: Basic Principles of Flow Measurement.
Module 3-6: Pressure-Sensing Devices.
Module 3-7: Flow-Sensing Devices: Differential-Pressure Flowmeters.
Module 3-8: Flow-Sensing Devices: Linear Flowmeters.

COURSE 4: HEAT TRANSFER AND FLUID FLOW.

Module 4-1: Basic Properties of Fluids.
Module 4-2: Fluid Statics.
Module 4-3: Fluid Dynamics.
Module 4-4: Heat Transfer by Conduction.
Module 4-5: Heat Transfer by Convection.
Module 4-6: Heat Transfer by Radiation.
Module 4-7: Change of Phase – Boiling.
Module 4-8: Burnout and Flow Instability.
Module 4-9: Reactor Heat Transfer Limits.

COURSE 6: INSTRUMENTATION AND CONTROL OF REACTORS AND PLANT SYSTEMS.

Module 6-1: Neutron Monitoring Systems.
Module 6-2: Neutron Sensors.
Module 6-3: Neutron Flux Signal Conditioning.
Module 6-4: Control-Rod Drives and Indicating Systems.
Module 6-5: Instrumentation Power Supplies.
Module 6-6: Installation of Instrumentation Systems.

COURSE 7: REACTOR OPERATIONS.

Module 7-1: Reactor Operator Licenses.
Module 7-2: Administrative Control for Nuclear Systems.
Module 7-3: Reactor Operating Experiences.
Module 7-4: Reactor Startup Procedures.
Module 7-5: Pressurized Water Reactor Operating Characteristics.
Module 7-6: Boiling Water Reactor Operating Characteristics.
Module 7-7: Refueling of Reactors.

COURSE 8: REACTOR SAFETY.

Module 8-1: Introduction to Reactor Safety.
Module 8-2: Reactor Licensing.
Module 8-3: Reactor Protection Systems.
Module 8-4 Reactor Emergency Systems.
Module 8-5: Safeguards and Security.

COURSE 9: REACTOR AUXILIARY SYSTEMS.

Module 9-1: Containment and Ventilation of Reactors.
Module 9-2: Spent Nuclear Fuel Storage and Handling Procedures.
Module 9-3: Emergency Power Systems for Reactors.
Module 9-4: Residual and Emergency Cooling Systems for Reactors.

COURSE 10: POWER PLANT SYSTEMS.

Module 10-1: Power Plant Fundamentals.
Module 10-2: Power Plant Thermal Cycles.
Module 10-3: Turbines and Generators.
Module 10-4: Heat Exchangers and Condensers.
Module 10-5: Pumps.
Module 10-6: Valves and Piping.
Module 10-7: Electrical Transmission and Distribution Systems.
Module 10-8: Power Plant Fundamentals (Fossil Fuel Energy Efficiency).
Module 10-9: Fossil Plant: Auxiliary Discussions.

COURSE 12: REACTOR PHYSICS.

Module 12-1: Neutron Physics.
Module 12-2: Cross Sections and Reactions.
Module 12-3: Fission Rate and Reactor Plant.
Module 12-4: Time Independent Nuclear Theory.
Module 12-5: Time Dependent Nuclear Theory.
Module 12-6: Reactivity – Fuel Moderator and Control Systems.
Module 12-7: Internal Effects of Reactivity.
Module 12-8: Reactor Operating Characteristics.

COURSE 15: METALLURGY AND METALS PROPERTIES.

Module 15-1: Fabrication Processes for Metals.
Module 15-2: Chemical Analysis of Metals.
Module 15-3: Basic Metallurgical Concepts.
Module 15-4: Properties of Steel.
Module 15-5: Metallographic Examination.
Module 15-6: Mechanical Testing – Tensile, Bend, Hardness.
Module 15-7: Mechanical Testing – Impact, Nick Break, Fatigue.
Module 15-8: Failure Mechanisms in Metals.

COURSE 16: MECHANICAL COMPONENT CHARACTERISTICS AND SPECIFICATIONS.

Module 16-1: Pump Characteristics and Specifications.
Module 16-2: Piping Characteristics and Specifications.
Module 16-3: Valve Characteristics and Specifications.
Module 16-4: Fastener Characteristics and Specifications.
Module 16-5: Lifting and Handling Equipment Characteristics and Specifications.
Module 16-6: Rotating Equipment Characteristics and Specifications.
Module 16-7: Heat Exchanger Characteristics and Specifications.
Module 16-8: Pressure Vessel Characteristics and Specifications.

COURSE 23: NUCLEAR CHEMICAL PROCESSES.

Module 23-1: Head-End Treatment.
Module 23-2: Ion Exchange.
Module 23-3: Solvent Extraction.
Module 23-4: Precipitation Techniques and Centrifugation.
Module 23-5: Techniques of Chemical Concentration.
Module 23-6: Diffusion and Enrichment Process.
Module 23-7: Nuclear Waste Handling Processes.

COURSE 24: NUCLEAR SYSTEMS AND SAFETY.

Module 24-1: Neutron Physics. (Same as Module 12-1.)
Module 24-2: Cross Sections and Reactions. (Same as Module 12-2.)
Module 24-3: Fission Rate and Reactor Power. (Same as Module 12-3.)
Module 24-4: Nuclear Criticality.
Module 24-5: Nuclear Material Inventory Management Techniques.
Module 24-6: Nuclear Plant Safeguards.

COURSE 25: RADIOACTIVE MATERIAL HANDLING TECHNIQUES.

Module 25-1: Glove Box Operations – Fundamentals.
Module 25-2: Glove Box Operations – Advanced.
Module 25-3: Master/Slave Manipulator – Fundamentals.
Module 25-4: Master/Slave Manipulator – Advanced.
Module 25-5: Remote Sampling Techniques.
Module 25-6: Waste Disposal Procedures. (Same as Module 21-1.)
Module 25-7: Packaging and Monitoring of Radioactive Materials for Shipment. (Same as Module 21-6.)
Module 25-8: Measurement of External Radiation Contamination. (Same as Module 21-4.)

COURSE 26: NONDESTRUCTIVE EXAMINATION (NDE) TECHNIQUES I.

Module 26-1 Visual Tests.
Module 26-2: Leak Tests.
Module 26-3: Hydrostatic Tests.
Module 26-4: Liquid Penetrant.
Module 26-5: Fundamentals of Radiography.
Module 26-6: Radiograph Inspection.
Module 26-7: Radiographic Specifications and Code Requirements.

COURSE 27: METROLOGY.

Module 27-1: Fundamentals of Metrology.
Module 27-2: Gixed Gages, Dividers, Calipers and Micrometers.
Module 27-3: Gage Blocks, Mechanical Comparators and Electronic Comparators.
Module 27-4: Angle Measurement Instruments, Optical Projectors and Surface Texture Gages.
Module 27-5: Tolerancing.
Module 27-6: Calibration Instruments.
Module 27-7: Statistical Techniques in Metrology.
Module 27-8: The Total Measurement System.

COURSE 28: WELDING INSPECTION.

Module 28-1: Welding Fundamentals and Processes.
Module 28-2: Shielded Metal Arc and Oxyacetylene Welding.
Module 28-3: Tungsten Inert Gas (TIG), Metal Inert Gas (MIG), and Submerged Arc Welding.
Module 28-4: Weld Joint Verification.
Module 28-5: Qualifications.
Module 28-6: Process Controls.
Module 28-7: Acceptance Inspection.
Module 28-8: Filler Material Control.
Module 28-9: Weld Repair Control.
Module 28-10: Records.

COURSE 29: CIVIL/STRUCTURAL INSPECTION.

Module 29-1: Inspection of Construction Operations.
Module 29-2: Structural Steel Materials, Installation and Inspection.
Module 29-3: Concrete Materials.
Module 29-4: Concrete Preparation, Production, Placement and Finishing.
Module 29-5: Concrete Testing and Inspection.
Module 29-6: Prestressed Concrete Materials, Fabrication and Inspection.

COURSE 30: MECHANICAL INSPECTION.

Module 30-1: Pump Inspection.
Module 30-2: Pump Functional Testing.
Module 30-3: Valve Inspection.
Module 30-4: Piping Inspection.
Module 30-5: Surface Cleaning Inspection.
Module 30-6: Protective Coating Inspection.
Module 30-7: Pressure Vessel Inspection.
Module 30-8: Rotating Equipment Inspection.

COURSE 31: QUALITY-ASSURANCE PRACTICES.

Module 31-1: Overall Quality Assurance Program.
Module 31-2: Vendor Qualification.
Module 31-3: Receiving Inspection.
Module 31-4: Identification, Storage and Handling of Components, Parts and Materials.
Module 31-5: Nonconforming Material.
Module 31-6: Certification and Qualification of Quality-Control Inspectors.
Module 31-7: Auditing for Quality Assurance.
Module 31-8: Document Handling, Storage and Retrieval for Quality Assurance.

COURSE 32: NONDESTRUCTIVE EXAMINATION (NDE) TECHNIQUES II.

Module 32-1: Fundamentals of Ultrasonic Testing.
Module 32-2: Operation of Ultrasonic Test Equipment.
Module 32-3: Fundamentals of Magnetic Particle Testing.
Module 32-4: Operation of Magnetic Particle Test Equipment.
Module 32-5: Fundamentals of Eddy Current Testing.
Module 32-6: Operation of Eddy Current Test Equipment.

COURSE 33: CONTROL SYSTEMS I.

Module 33-1: Introduction to Block Diagrams.
Module 33-2: Input/Output Devices.
Module 33-3: Control System Theory.
Module 33-4: Pneumatic Control Mechanisms.
Module 33-5: Control Valves.
Module 33-6: Process Control Characteristics.

COURSE 34: CONTROL SYSTEMS II.

Module 34-1: Introduction to Transfer Functions.
Module 34-2: Frequency Response Analysis.
Module 34-3: Combination Control Systems.
Module 34-4: Controller Tuning.
Module 34-5: Operational Amplifiers.
Module 34-6: Microprocessor Utilization.
Module 34-7: Microprocessor Programming.

COURSE 35: POWER PLANT ELECTRICAL SYSTEMS AND COMPONENTS.

Module 35-1: Electrical Distribution.
Module 35-2: Instrumentation and Control for Major Plant Components.
Module 35-3: Recording and Display Devices.
Module 35-4: Process Control Loops and Devices.
Module 35-5: Cathode Ray Tube Systems (CRT).
Module 35-6: Preventive Maintenance for Systems and Components.
Module 35-7: Instrument Reliability.

APPENDIX C

SUGGESTED WORKFORCE NEEDS SURVEY INSTRUMENT FOR RADIATION PROTECTION TECHNICIAN

Dear Sir:

I am writing to ask for your help. Our school is considering the establishment of a 2-year technical program in the new field of radiation protection technology. Prior to establishing such a program, I have been asked to conduct a survey of the present and future needs in this locale for technicians with this special training. I have enclosed the survey, which should take just a few minutes to compiete. When you are done, simply place this survey in the enclosed stamped addressed envelope and return. If you wish a copy of the results of the survey, please so indicate at the end of the questionnaire.

If, for some reason, this questionnaire does not apply to your specific area of responsbility at your organization, please pass it on to someone to whom it may be more appropriate.

I appreciate your efforts in behalf of this new occupational training program in the state.

Sincerely,

_____
Title

TYPICAL WORKFORCE NEEDS SURVEY INSTRUMENT FOR RADIATION PROTECTION TECHNICIANS

Name of company, institution, or government division:

_____

_____

Definitions: Radiation Protection Technician.

Under the direction of a health physicist, performs radiation surveys to provide valid data for control of personnel radiation exposure, radioactive contamination, radioactive waste disposal, shipment and receipt of radioactive materials, and trains other personnel in the proper use of monitoring equipment. Keeps records and is responsible for radiation safety equipment and supplies. Recommends procedures to minimize exposures and contamination during routine operation.

Yes No

1. _____ _____ Does your company currently employ people who are trained or under training as Radiation Protection Technicians?
2. _____ _____ Do you have current vacancies for Radiation Protection Technicians?
3. Please indicate the typical beginning salary a Radiation Protection Technician might expect to receive in your company.

a. $700-800/mo. _____
b. $801-1000/mo. _____
c. $1001-1200/mo. _____
d. $1201-1400/mo. _____
e. $1401-1600/mo. _____
f. Greater than $1600/ mo. _____

4. In your opinion, your need for Radiation Protection Technicians during the next ten years will:

_____ decrease
_____ remain the same
_____ increase by 0-25%
_____ increase by 26-50%
_____ increase by 51-75%
_____ increase 76-100% or more

5. Can you give an estimate of the total number of Radiation Protection Technicians you will need in the next five year period?

1980 _____
1981 _____
1982 _____
1983 _____
1984 _____

6. As you employ Radiation Protection Technicians in the future would you:

_____ prefer to train these individuals yourself?
_____ prefer to hire individuals trained in nuclear fundamentals in a recognized and approved institution?

7. Please circle those items in which you think the Radiation Protection Technician should receive specific training:

I. Physical properties of radiation.
   A. Laws of absorption.
   B. Intensity – distance relationships.
   C. Deviations from simple laws.
II. Established maximum exposure limits.
III. Design, components and funcations of reactivity control mechanisms and instrumentation.
IV. Design, components and functions of safety systems.
   A. Instrumentation.
   B. Signals.
   C. Interlocks.
   D. Automatic and manual features.
V. Shielding, isolation and containment procedures for the facility/plant (specific).
VI. Collection and analysis of radioactive samples of gaseous and liquid effluent and environmental media.
VII. Conduction of radiation and contamination surveys for reactor operation.
VIII. Maintenance of records and environmental releases, isotope releases, and personnel exposure.
IX. The obtaining of sample preparations for irradiation and counting.
X. Preparation and monitoring of radioactive waste shipments.
XI. Maintenance and calibration of detection instruments.

XII. Trains others in basic radiation protection and regulations.

XIII. Familiarity with radiation source equipment.

A. Presence or absence of primary beam absorber.

B. Leakage radiation (radiation through source shield).

C. Type of equipment (whether constant output or pulsating.

D. X-ray tube current or output in roentgens per minute.

XIV. Layout of rooms or areas in which source is located.

A. Wall, floor, and ceiling thickness.

B. Type of existing or planned structural material.

C. Location with respect to other areas and persons.

D. Protective barrier material used to supplement structural material.

XV. Other – Please list.

_____

_____

_____

8. Due to specific duties, titles for a Radiation Protection Technician may vary; which of the following titles are used by your company to describe these individuals?

_____ Radiation Protection Technologist.

_____ Health Physics Technician (or Monitor).

_____ Radiation Control Technician.

_____ Radiation Monitor.

_____ Nuclear Spent Fuel Transport Technician.

_____ Radiation Safety Assistant or Technician.

_____ Health and Safety Technician.

9. Please indicate the type of radiation source(s) your company uses:

_____

_____

_____

_____

10. Would you classify our company's principal endeavor as:

_____ Electrical power production (nuclear).

_____ Industrial research and development (nuclear).

_____ Hospital service (nuclear).

_____ Nuclear materials processing and disposal.

_____ Industrial radiography service.

_____ Equipment manufacturer.

_____ Oil well logging.

_____ University or private training consultant.

_____ Shipyard service.

_____ Other (specify) _____

_____

_____

11. Comments: Please include any additional information which you feel would help us identify the need in numbers and competencies for Radiation Protection Technicians.

_____

_____

_____

_____

Yes No

12. _____ _____ Would you like to receive a copy of the report summarizing the results of this survey?

Please mail to: _____

_____

_____

_____

Your kind assistance in completing this survey questionnaire is appreciated.

APPENDIX D

UNIVERSITIES WITH RESEARCH REACTORS

Brigham Young University (L-77)
California State Polytechnic College (AGN-201)
Catholic University (AGN-101)
Columbia University (TRIGA)
Cornell University - Zero Power Reactor (ZPR)
Cornell University (TRIGA)
Massachusetts Institute of Technology (CP-5)
Michigan State University (TRIGA)
North Carolina State University (POLSTAR)
Ohio State University
Oregon State University (TRIGA)
Penn State University (TRIGA core)
Purdue University
Reed College (TRIGA)
Rhode Island (AEC)
State University of New York (POLSTAR)
Stanford University
Texas A & M (TRIGA)
Texas A & M (AGN-201M)
Tuskegee Institute (AGN-201)
University of Arizona (TRIGA)
University of California at Irvine (TRIGA)
University of California at Los Angeles (Argonaut)
University of California at Santa Barbara (L-77)
University of Delaware (AGN-201)
University of Florida (Argonaut)
University of Illinois (TRIGA)
University of Illinois (LPRA)
University of Kansas
Georgia Institute of Technology (CP-5)
Idaho State University (AGN-201)
Iowa State University
Kansas State University (TRIGA)
University of Lowell
Manhattan College
University of Maryland (TRIGA)
University of Michigan
University of Missouri at Rolla
University of Missouri at Columbia
University of New Mexico (AGN-201)
University of Oklahoma (AGN-201)
University of Texas (TRIGA)
University of Utah (AGN-201)
University of Virginia (Pool)
University of Virginia (Cavalier)
University of Washington
University of Wisconsin (TRIGA core)
Virginia Polytechnic Institute
Washington State University (TRIGA core)
West Virginia University
Worcester Polytechnic University
Memphis State University (AGN-201)

APPENDIX E

EQUIPMENT LIST WITH COST, QUANTITY AND VENDOR DATA

COURSE	RADIATION EQUIPMENT	UNIT COST	QUANTITY REQUIRED	TOTAL COST
1	Alarm Monitor, 1 per entrance to radiation area	475	1	475
20; 21; 22	Analyzer, Multi-channel pulse height	8,500	1	8,500
19	Bonner Neutron Spectrometer	1,700	1	1,700
1	Chart of Nuclides	3	3	9
1	Coats, white knee-length lab (disposable)	64/65	50	128
11; 22	Counter, LSC NOTE: Less sophisticated counting equipment may be substituted for this counting system, but with a resultant decrease in counting efficiency.	20,000	1	20,000
17; 20; 21; 22	Counter, β^-	1,200	3	3,600
	Counter, α	1,300	3	3,900
18	Coveralls, anti-C, with hood (disposable)	10 ea	48	480
	Covers, shoe (disposable)	3/pr	48pr	144
	Decontamination kit with radiation signs and labels, rope, cleaner, drum, brushes	220	1	220
11; 17	Densitometer	4,900	1	4,900
	Developing Tank, 2 gallon stainless steel	75	2	150
1	Dosimeters, direct reading pocket	80	48	3,840
	Dosimeter charger	65	5	325
11; 17	Dosimetry film, commercial personnel monitor type (Type NTA & Type 3)	75/box	1 box each	150
1; 11; 17	Dosimeter, Thermoluminescent (TLD)			
	Annealed Calibration Source	600	1	600
	Holder	8	72	576
	Reader	5,700	1	5,700
	TLD Chips, TLD 100 (LiF, CaF_2)	100/10	240	2,400
11; 19; 21	Electrometer	300	1	300
1	Film badge	10/ass't	1 ass't	10
1; 11; 17	Forceps	1	25	25
	Fume Hood, Radioisotopic	5,000	3	15,000
1; 11; 17; 20	Furnace, Muffle	375	1	375
11; 17; 22	GeLi detector, with shielding and liquid nitrogen coolant NOTE: Less sophisticated counting equipment may be substituted for this counting system, but with a resultant decrease in counting efficiency.	50,000	1	50,000
1;18;21;22	Glove box, radioisotopic	3,500	2	7,000
	Gloves, disposable rubber or plastic	15/100pr	500 pr	75
1;11;18;19;21	G-M detector, end-window	125	12	1,500
	G-M detector, side window	75	12	900
2;11;19	Ionization counter, 2π gas-flow type	1,500	2	3,000
19;21	Micro-R meter, gamma sensitive, scintillation	775	1	775
18	Mask, full-face with breathing apparatus	225	4	900
11;19;20;21;22	NaI(Tl) scintillation detectors, 1/2" x 1 3/4", with photomultiplier and pre-amplifier	250	12	3,000
18;19	Neutron detector	1,100	1	1,100
19	Neutron source (Pu-Be) Obtainable from DOE for shipping costs		1	
all	Radioactive sources, exempt quantities	850	1 ass't	850
1;5;11;19;20;21	Scaler-Ratemeters	1,500	12	18,000
18;21	Smear discs, with holders	40/box	1 box	40

Estimated equipment costs based on 1979 prices.

COURSE	RADIATION EQUIPMENT	UNIT COST	QUANTITY REQUIRED	TOTAL COST
20	Spectrograph, gamma	2,800	1	2,800
all	Storage container, radioactive waste	275	1	275
11;18	Survey meter, ionization type	660	2	1,320
5;11;18	Survey meter, neutron	1,220	2	2,440
all	Survey meter, portable G-M	600	12	7,200
11;22	Vials, LSC with tops	76/500	500	76
all	Workbench modules			
	Decay cabinet	1,300	12	15,600
	Sink and waste	1,850	12	22,200
	Storage	3,000	12	36,000
				248,558
	DIMENSIONAL			
20	Caliper, micrometer	34	12	420
20	Caliper, vernier	17	12	204
all	Meter stick	3	12	36
1	Yardstick	2	4	8
				668
	ELECTRICAL			
10	a.c. generator	145	1	145
17	Camera, closed circuit with monitor	1,200	1	1,200
3	Decade resistance box (5 place)	125	1	125
13	Electrodes, glass and reference	350/set	1 ass't	350
3;13	Millivoltmeter (0-500 mV)	200	12	2,400
1,11	Oscilloscope, cathode-ray	1,500	1	1,500
3	Potentiometer, dial type with built-in standard cell	600	1	600
13;21	pH meter	940	1	940
3	Voltmeter, 3.5 digit (0-50 mV)	100	12	1,200
				8,460
	HARDWARE			
3;10	Pipe and assorted fittings, galvanized	100	1 ass't	100
13	Signal cable	2/ft	100 ft	200
3;13;22	Tubing:			
	Glass	68/25#	50#	136
	Koroseal	175/50 ft	100 ft	350
	Rubber	50/12 ft	100 ft	420
3;5;10	Valve assortment: air vent; butterfly; check; diaphragm; gate; globe; motor actuated; plug; Y pattern; 3-way; 4-way; needle	200	1 ass't	200
				1,406
	CHEMICAL			
20;21;22	Absorption train, gas	250	1	250
20;21;22	Adsorption column sampling apparatus	475	1	475
13;22	Cartridge filter, 1 each of carbon, sediment, demineralizer, and sub-micron	45	1 set of 4	180
13;22	Cartridge filter housing	35	4	140
20	Gas generator	175	1	175
13;20;21;22	Ion-exchange column tubes	15	6	90
13;22	pH buffer solutions	50/set	1 set	50
13;22	pH test paper	10/set	4 sets	40
13;20;22	Resin, ion-exchange chloride form, 50-100 mesh	8/lb	5 lb	40
13;20;22	Resin, ion-exchange weak acid form; 50-100 mesh	5/lb	5 lb	25
				1,465

Estimated equipment costs based on 1979 prices.

COURSE	TYPE OF EQUIPMENT	UNIT COST	QUANTITY REQUIRED	TOTAL COST
	TEMPERATURE MEASUREMENT			
3	Resistance temperature detector			
	open wire element, 100	725	1	725
	Standard platinum, 100	725	1	725
3;17	Temperature recorder	720	1	720
3;13;17	Thermometers:			
	General laboratory	40/5	ass't	200
	NBS 2° standard, total immersion, -10° to 100°C	740	1	740
	NBS Test Thermometer	26	12	312
3	Wire			
	Copper lead	2.50/ft	250 ft	625
	Thermocouple	160/50	50 ft	160
				4,207
	MECHANICAL			
22	Air pump	50	1	50
20	Aspirator, hand, 100 ml	300	1	300
3	Barometer, mercury	280	1	280
5;13	Centrifugal pump (~30 gpm)	450	1	450
13	Extensometer, tensile test	7,500	1	7,500
3;10	Flow meter, rotating turbine	325	1	325
3	Gages:			
	Hydraulic press and pressure	95	1	95
	Instrument, air:			
	High volume	750	1	750
	Low volume	750	1	750
	Pressure	75	2	150
3;10	Manometer, 30 inch U-tube	85	2	170
13	Nitrogen tank	95	1	95
3	Orifice plates	8	3	24
13	Oxygen tank	95	1	95
3	Rotameter	275	1	275
13	Samples of iron, aluminum, copper, low-carbon steel, medium-carbon steel, high-carbon steel, cast iron, alloy steel, chromium steel	~10	1 of each	80
10	Shaft eccentricity detector	45	1	45
10	Shaft vibration measurement instrument	55	1	55
20	Shears, metal hand	10	1	10
10	Steam turbine, small	155	1	155
20	Tongs, remote handling, 30 inch, assorted sizes	500/set	2 sets	1,000
3	Venturi tube	15	1	15
				12,669
	AUXILIARY			
1;19;22	Absorbers, aluminum and lead	180/set	6 sets	1,080
11;19;21;22	Absorbers, 4 x 4 inch square:			
	lead 1/16 inch	5	10	50
	lead 1 mm	5	10	50
	aluminum 1/16 inch	4	10	40
	lucite 1/16 inch	4	10	40
	glass 1/16 inch	3	10	30
	plastic 1/8 inch	3	10	30
	iron 1/16 inch	4	10	40
13;20;21;22	Balance, analytical	1,300	2	2,600
20;21;22	Balance, triple beam	95	2	190
17	Bath, boiling water	40	6	240
3;13;20;21	Beakers, with spout, 50-1000 ml sizes	110/12 sets	sets	110
all	Bricks, lead	35	48	1,680
13	Buret, 50 ml	85/4	12	255
20;21	Centrifuge, 50 ml	395	1	395
13;22	Cylinder, graduated 10-2000 ml sizes	140/set	4 sets	560
17	Darkroom for X-ray film development	2,000	1	2,000
3;13;20;22	Desiccator	70	6	420

Estimated equipment costs based on 1979 prices.

COURSE	TYPE OF EQUIPMENT	UNIT COST	QUANTITY REQUIRED	TOTAL COST
17	Electrodeposition analysis apparatus	1,400	1	1,400
1;11;17;20;21; 22	Evaporating dish, 1 liter capacity	350	3	1,050
17	Filter disc, glass fiber	40	1 ass't	40
11;13;20;22	Filters, low Z	10	36	360
13;17;20;21;22	Filter paper	40	1 ass't	40
3;13;17;20;21;22	Flasks:			
	Dewar, with holder	180/6	6	180
	Erlenmeyer, 50-500 ml sizes	80/12 sets	12 sets	80
	Vacuum, 50 and 1000 ml sizes	180/12 sets	12 sets	180
	Volumetric, 50-1000 ml sizes	600/12 sets	12 sets	600
20;21;22	Funnel, separatory, 250 and 500 ml sizes	160/4 sets	4 sets	160
all	Holder, sample	85	12	1,020
3;13;20;21;22	Hot plate, motorized stirrer	140	3	420
1;13;20;21;22	Lamp, infra-red heat	20	12	240
	with motorized sample spinner	200	1	200
all	Liner, absorbent, for plastic tray	35/cs.	2	70
17	Mirror	8	12	96
13;17;20;21;22	Oven, drying	600	3	1,800
1;11;13;17;20;22	Pipette:			
	Disposable serological, 1, 5, and 10 ml sizes	400/3case	1 each	400
	Eppendorf λ, 2-100 λ sizes with tips	850/set	3 sets	2,550
	Volumetric, 1, 2, 3, 5-100 ml sizes	35/set	6 sets	210
17	Pipettor, remote 30 inch	200	4	800
all	Planchet, assortment	200	1	200
all	Ringstand, with base	225/12	24	450
20;22	Sampler, air:			
	High volume	275	1	275
	Low volume	450	1	450
22	Sieves	175/set	1	175
13;17;20;21;22	Stirrer, magnetic	90	6	540
1;2;3;11;20; 21;22	Stopwatch	125	2	250
3	Telescope; 10x with mount	100	1	100
11;13;17;20	Timer	135	12	1,620
all	Tray, plastic	26	24	624
3;13;20;21;22	Tubes, test, assorted sizes	45/24 sets	48 sets	90
				24,860

NOTE: Items mentioned in this list should not be construed as absolute requirements for performance of laboratory exercises in this curriculum. This list is supplied as an indication to the instructor of the scope of laboratory work covered. The instructor should differentiate between those items that will be basic to laboratory procedures and those that may be required at a later date.

For courses requiring film badge service for continuous recording of radiation, a cost of $45.00 for 20 badges should be allowed for each quarter.

Estimated equipment costs based on 1979 prices.

PARTIAL LIST OF EQUIPMENT SOURCES

VENDORS

The following list indicates companies that provide catalogs or information used in the preparation of this Guide. It is not a comprehensive list, and no endorsement of these companies or their equipment is intended or implied.

ALPHA DIVISION
Ventron Corporation
P. O. Box 299
152 Andover Street
Danvers, MA 01923

ATOMIC PRODUCTS CORPORATION
Atomlab Division
P. O. Box 657
Center Moriches, NY 11934

CENTRAL SCIENTIFIC COMPANY
2600 South Kostner Avenue
Chicago, IL 60623

CURTIN MATHESON SCIENTIFIC, INC.
A Coulter Subsidiary Company
CMS International Division
P. O. Box 1546
4220 Jefferson Avenue
Houston, TX 77001

DEFENSE APPAREL-NUCON PRODUCTS
P. O. Box 14703
163 Murphy Road
Hartford, CT 06114

THE EALING CORPORATION
22 Pleasant Street
South Natick, MA 01760

FISHER EDUCATIONAL MATERIALS DIVISION
4901 West Lemoyne Avenue
Chicago, IL 60651

THE HARSHAW CHEMICAL CO.
Crystal and Electronic Products Department
6801 Cochran Road
Solon, OH 44139

JORDAN NUCLEAR COMPANY
3244 Arroyo Seco Avenue
Los Angeles, CA 90065

R. S. LANDAUER, JR. & CO.
Glenwood Science Park
Glenwood, IL 60425

LUDLUM MEASUREMENTS, INC.
501 Oak Street
Sweetwater, TX 79556

NUCLEAR ASSOCIATES, INC.
Radiation-Medical Products Corporation
100 Voice Road
Carle Place, NY 11514

VICTOREEN, INC.
10101 Woodland Avenue
Cleveland, OH 44104

SARGENT-WELCH SCIENTIFIC CO.
7300 North Linder Avenue
Skokoe, IL 60076

TECH/OPS RADIATION PRODUCTS DIVISION
Northwest Industrial Partk
Burlington, MA 01803

U.S. DEPARTMENT OF ENERGY (DOE)
(Formerly ERDA) Surplus Equipment List
See Catalog of Federal Domestic Assistance,
available from the Superintendent of
Documents, Washington, DC 20402

APPENDIX F

SUGGESTED LIBRARY REFERENCES AND MATERIALS

BOOKS

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IAEA. Radioactive Waste Disposal into the Ground. New York: Unipub, Inc.

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USNRC. Code of Federal Regulations, Title 10. U.S. Government Printing Office. This document is updated and reissued every year. Supplements are issued through the year by NRC.

U.S. Nuclear Regulatory Commission Guides. Available from the Director of Regulatory Standards, USNRC, Washington, D.C.

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Zweifel, Paul Frederick. Reactor Physics. New York: McGraw-Hill Book Company, 1973.

JOURNALS (NUCLEAR)

ATOMIC DATA AND NUCLEAR DATA TABLES
Academic Press, Inc.
111 Fifth Avenue
New York, NY 10003

ATOMIC ENERGY CLEARINGHOUSE
Congressional Information Bureau, Inc.
Colorado Bldg., 14th & G Streets, N.W.
Washington, DC 20005

HANFORD NEWS
Department of Energy
Atlantic Richfield Hanford Co.
P. O. Box 250
Richland, WA 99352

HEALTH PHYSICS JOURNAL
(See Associations and Societies)
4720 Montgomery Lane, Suite 506
Bethesda, MD 20014

INIS ATOMINDEX
UNIPUB
P. O. Box 433
Murray Hill Station
New York, NY 10016

INSTITUTION OF NUCLEAR ENGINEERS JOURNAL
(Formerly NUCLEAR ENERGY)
Institute of Nuclear Engineers
1 Penerley Rd.
London SE6 2LQ, England

NUCLEAR INDUSTRY STATUS
Nuclear Assurance Corp.
24 Executive Park West
Atlanta, GA 30329

NUCLEAR INFO
Atomic Industrial Forum
475 Park Avenue South
New York, NY 10016

NUCLEAR INSTRUMENTS AND METHODS
North Holland Publishing Co.
Box 211
Amsterdam, Netherlands

NUCLEAR MATERIALS MANAGEMENT
Institute of Nuclear Materials Management
Seaton Hall
18 Seaton Hall
Manhattan, KS 66506

NUCLEAR NEWS
American Nuclear Society
244-a, E. Ogden Avenue
Hinsdale, IL 60521

NUCLEAR POWERPLANT PERFORMANCE
Nuclear Assurance Corp.
24 Executive Park West
Atlanta, GA 30329

NUCLEAR SAFETY
U.S. Nuclear Regulatory Commission Publication
Superintendent of Documents
Government Printing Office
Washington, DC 20402

NUCLEAR STANDARD NEWS
American Nuclear Society
244 E. Ogden Avenue
Hinsdale, IL 60521

JOURNAL OF NUCLEAR MATERIALS
North Holland Publishing Co.
Box 211
Amsterdam, Netherlands

JOURNAL OF NUCLEAR SCIENCE AND TECHNOLOGY
Atomic Energy Society of Japan
% Japan Atomic Energy Research Institute
1-13 Shimbashi, Minato-Ku
Tokyo, Japan

JOURNAL OF PHYSICS: NUCLEAR PHYSICS
Institute of Physics
47 Belgrave Square
London SWIX 8QX, England

NUCLEAR FUEL STATUS AND FORECAST
Nuclear Assurance Corp.
24 Executive Park West
Atlanta, GA 30329

NUCLEAR TECHNOLOGY
American Nuclear Society, Inc.
244 E. Ogden Avenue
Hinsdale, IL 60521

NUCLEONICS WEEK
McGraw-Hill, Inc.
1221 Avenue of Americas
New York, NY 10020

OAK RIDGE ASSOCIATED UNIVERSITIES NEWSLETTER
Oak Ridge Associated Universities, Inc.
Information Services Dept.
Box 117
Oak Ridge, TN 37830

OAK RIDGE NATIONAL LABORATORY REVIEW
Oak Ridge National Laboratory
P. O. Box X
Oak Ridge, TN 37830

AGENCIES, ASSOCIATIONS AND SOCIETIES

Additional relevant reference materials may be obtained directly from the following sources.

AGENCIES

International Atomic Energy Agency (IAEA)

IAEA Proceedings and Directory available for purchase from its Division of Publications.

International Commission on Radiation Units and Measurements (ICRU)

International Commission of Radiological Protections (ICRP)

National Council on Radiation Protection and Measurements (NCRP)

United Nations Scientific Committee on the Effects of Atomic Radiation

United States Government

Department of Energy
Nuclear Regulatory Commission

All NRC/DOE documents are available for purchase from the National Technical Information Service of the U.S. Department of Commerce, 5285 Port Royal Road, Springfield, VA 22151

ASSOCIATIONS AND SOCIETIES

American National Standards Institute

ANSI Standards

American Nuclear Society (ANS)

American Society of Mechanical Engineers (ASME)

American Society of Quality Control (ASQC)

American Society for Testing Materials

American Welding Society

Atomic Industrial Forum (AIF)

Health Physics Society

AUDIO VISUAL AIDS

In addition to aids used by the instructor(s), there are available films and other pertinent materials showing research or production that should be available to students of nuclear technology on a selective basis. Frequently these items can be made available by equipment vendors, utility companies, Government agencies and other organizations that may be represented on a program's industrial advisory committee.

Babcock and Wilcox
Manager, Special Products & Service Marketing
Nuclear Power Generation Division
Lynchburg, VA 24505

General Electric Company
Manager - BWR Training
Mail Code 594
175 Curtner Avenue
San Jose, CA 95125

DOE - Technical Information Center
Oak Ridge National Laboratory
P. O. Box 62
Oak Ridge, TN 37830

U.S. Department of Health, Education & Welfare
Public Health Service
Bureau of Radiological Health
Rockville, MD 20852

Training Resources Center
5600 Fishers Lane
Rockville, MD 20852

American Society of Mechanical Engineers
Education Division
345 East 47th Street
New York, NY 10017

American Nuclear Society
555 North Kensington Avenue
La Grange Park, IL 60625

Health Physics Society
4211 39th Street, NW
Washington, DC 20016

APPENDIX G

SAMPLE COSTING CALCULATIONS

SAMPLE CALCULATION NO. 1

(Two faculty members and full enrollment of students)

Assumptions:
- 24 1st-yr students.
- 16 2nd-yr students.
- 14 grads annually after 2nd yr.
- 1 Dept. head @ $24,000 - 1st yr salary.
- 1 Instructor (beginning 2nd yr) @ $18,000 - 1st yr salary.
- 1/2 Secretary @ $8,000 - 1st yr salary.
- Benefits and overhead equal to 50% of annual salaries.
- Facility modifications cost of $31,250.
- Initial capital equipment cost of $88,500 (for 1st-yr courses only).
- Additional capital equipment cost of $113,500 for 2nd-yr courses.
- Annual expendables cost of $13,000 for both 1st- and 2nd-yr courses.
- Miscellaneous annual costs of $5,000 (library, travel, seminars, etc.).

Calculation:

Initial expenditures	Facility	$ 31,250.00		
	Equipment	88,500.00		
			$ 119,750.00	
1st-yr expenditures	Dept. head	$ 24,000.00		
	Secretary	4,000.00		
	Benefits & Overhead	14,000.00		
	Expendables	6,500.00		
	Misc.	2,500.00	51,000.00	
			$ 170,750.00	$ 170,750.00
2nd-yr equipment expenditures			$ 113,500.00	
2nd-yr expenditures	Dept. head	$ 24,000.00		
	Secretary	4,000.00		
	Instructor	18,000.00		
	Benefits & Overhead	23,000.00		
	Expendables	13,000.00		
	Misc.	5,000.00	87,000.00	
			$ 200,500.00	$ 200,500.00
				$ 371,250.00

If equipment and facilities costs are developed over a five-year period, the following approximations apply:

Exp. Item	1st Yr	2nd Yr	3rd Yr	4th Yr	5th Yr
Personnel*	$ 28,000	$ 47,400	$ 49,770	$ 52,260	$ 54,870
Benefits & Overhead	14,000	23,700	24,885	26,130	27,435
Equipment	10,000	25,750	25,750	25,750	25,750
Facilities	6,250	6,250	6,250	6,250	6,250
Expendables	6,500	6,500	6,500	6,500	6,500
Miscellaneous	2,500	5,000	5,000	5,000	5,000
Annual Totals	$ 67,250	$114,600	$118,155	$121,890	$125,805

*5% annual salary increase included.

SAMPLE CALCULATION NO. 2

(One faculty member and minimum enrollment.)

Assumptions:
12 1st-yr students.
8 2nd-yr students.
6 grads annually after 2nd yr.
1 Dept. head/instructor @ $20,000 - 1st-yr salary.
1/2 Secretary @ $7,000 - 1st-yr salary.
Benefits and Overhead equal to 40% of annual salaries.
Facility modification cost of $6,000.
Initial capital equipment cost of $45,000 (for 1st-yr courses only).
Additional capital equipment cost of $65,000 for 2nd-yr courses.
Annual expendables cost of $6,500 for both 1st- and 2nd-yr courses.
Miscellaneous annual costs of $5,000 (library, travel, seminars, etc.).

Calculation:

Initial expenditures	Facility	$ 6,000.00		
	Equipment	45,000.00		
			$ 51,000.00	
1st-yr expenditures	Dept. head	$ 20,000.00		
	Secretary	3,500.00		
	Benefits and Overhead	9,400.00		
	Expendables	3,000.00		
	Misc.	5,000.00		
			40,900.00	
			$ 91,900.00	$ 91,900.00
2nd-yr equipment expenditures			$ 65,000.00	
2nd-yr expenditures	Dept. head	$ 21,000.00		
	Secretary	3,700.00		
	Benefits and Overhead	12,350.00		
	Expendables	6,500.00		
	Misc.	5,000.00		
			48,550.00	
			$ 113,550.00	$113,550.00
				$205,450.00

If equipment and facilities costs are developed over a five-year period, the following approximations apply:

Exp. Item	1st Yr	2nd Yr	3rd Yr	4th Yr	5th Yr
Personnel*	$ 23,500	$ 24,700	$ 25,935	$ 27,237	$ 28,593
Benefits and Overhead	9,400	9,880	10,374	10,892	11,437
Equipment	11,000	25,000	25,000	25,000	25,000
Facilities	1,200	1,200	1,200	1,200	1,200
Expendables	3,200	6,500	6,500	6,500	6,500
Miscellaneous	2,000	5,000	5,000	5,000	5,000
Annual Totals	$ 50,300	$ 72,280	$ 74,009	$ 75,823	$ 77,730

*5% annual salary increase included.

SAMPLE CALCULATION NO. 3

(Industrial Training Facility)

Assumptions:
- Facility diversion: $60,000
- Equipment diversion: $55,000
- On-staff instructor(s) - annual salary $28,000.
- 1/2 Secretary - annual salary $9,000.
- Benefits and Overhead - 50% of annual salaries.
- Annual expendables cost of $1,200/student.
- Miscellaneous cost of $300/student.
- 10 students/yr.

Calculation:

1st-yr expenditures		
	Facility	$ 60,000.00
	Equipment	55,000.00
	Instructor	28,000.00
	Secretary	4,500.00
	Benefits and Overhead	16,250.00
	Expendables	12,000.00
	Misc.	3,000.00
		$178,750.00

NOTE: This calculation suggests costs for academic preparation only; it does not include observation, simulator training or coaching for NRC license examination.

ESTIMATED LIBRARY MATERIAL COST

Library materials for this technology, predicated on 1979 costs, may be estimated from the following:

Initial Costs	Minimum
References	$ 1,500.00
Journals	200.00
Periodicals	100.00
Miscellaneous (subscriptions, etc.).	50.00
	$ 1,850.00

Annual Costs	
References	$ 175.00
Journals	175.00
Periodicals	100.00
Miscellaneous (subscriptions, etc.).	50.00
	$ 500.00